RESPONSE OF SUGARCANE AND TWO ANNUAL WEEDY GRASSES TO s-TRIAZINE HERBICIDE - SURFACTANT COMBINATIONS

by

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TO

My wife, Satya Vati Singh and our two daughters, Manisha and Mani, whose patience and cooperation made this task possible.

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Seven surfactants and Sun Oil 11E reduced surface tension and contact angle of distilled water. Surfactant-WK (dodecyl ether of polyethylene glycol) was most effective and Tween-20 (polyoxyethylene sorbitan monolaurate) was least effective in reducing these values. Increasing concentration of surfactants from 0 to 0.1% (v/v) gave continuous reduction in surface tension and contact angle while higher concentrations, 0.1 to 2.0% (v/v) had no further effect. Water hardness up to 1,000 ppm as Ca ions did not affect surface tension and contact angle in surfactant solutions. The commercial wettable powder formulation of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) had higher surface tension and contact angle than the commercial wettable powder formulation of ametryne (2-ethylamino-4-isopropylamino-6-methylthio-s-triazine) in the absence of surfactants; no differences were observed when surfactants were added to either formulation.

Atrazine at 1.12 and ametryne at 0.56 kg/ha with 0.50 or 1.0% (v/v) concentrations of Surfactant-WK, Span-20 (sorbitan monolaurate), and Tween-20 effectively controlled both annual grasses; Alexandergrass (Brachiaria plantaginea (Link) A. Hitchc.) and broadleaf panicum (Panicum adspersum Trin.), in sugarcane (Saccharum hybrids). However, ametryne with all surfactants and atrazine with Surfactant-WK were phytotoxic to the crop and reduced numbers, height, and weight of plants. Herbicidal activity of atrazine and ametryne was increased by all surfactants, probably due to increased wettability and possible increase in cuticular absorption. Surfactant-WK alone was phytotoxic to sugarcane and both grass species and phytotoxicity increased with an increase in concentration from 0.50 to 2.0% (v/v). Atrazine at 1.12 and ametryne at 0.56 kg/ha were more active at higher temperatures and the influence of relative humidity was more critical at lower temperatures.

INTRODUCTION

Sugarcane (Saccharum hybrids) is an important source of sucrose, sugar being an integral part of the human diet and an important source of energy. Sugarcane is grown mainly between latitudes 30° N and 30° S on variable soils and at altitudes ranging from sea level to over 1,000 meters. The world's sugarcane is grown on about 8.5 million hectares of land with a production of nearly 465 million metric tons of sugarcane and 53 million metric tons of sugar per year. About 30 million metric tons of sugarcane and 3 million metric tons of sugar are produced annually in the United States on about 380,000 hectares. In Florida, sugarcane is one of the most important agricultural industries; approximately 120,000 hectares produced about 9,825,000 metric tons of sugarcane from which were processed about 950,000 metric tons of raw sugar in the 1975-1976 crop.

Sugarcane is a perennial, tropical grass which grows best under warm temperatures, adequate amounts and distribution of rainfall or irrigation, and insolation. Vegetative and maturation periods define the crop cycle which ranges from 10 to 24 months, or longer, depending upon geographic location. The several agronomic problems associated with the successful production of sugarcane can be resolved partly by selecting the most suitable agroclimatic areas for

the growth of the crop, ensuring adequate amounts of essential nutrients, and growing varieties of the highest production potential. These problems are common and vary from one part of the world to another. The problem of pest control varies with the intensity of infestation by respective types of pests. The conditions suitable for growing sugarcane are quite favorable for the attack by various pests which can be categorized as insects, diseases, nematodes, rodents, and the weeds.

Sugarcane is propagated vegetatively by planting stem pieces on which a dormant bud is located at each node. These buds grow actively in 3 to 6 weeks after planting depending upon the soil temperature. The germination and growth of weeds may be faster than that of sugarcane and fields can become heavily infested by weeds before emergence of the crop plants. Even after the crop has emerged, it may be smaller than many weeds and unable to compete, especially during cool winter months. Weeds compete with crop plants for light, moisture, nutrients, and space, and crop growth may be reduced considerably if they are not controlled. Weeds also may cause considerable loss in the later stages of crop growth up to and including harvesting. Weeds are estimated to reduce yields of sugarcane in the world as a whole by 15% or $1.5 billion annually (Cochrane and Procter 1970).

Several mechanical and cultural methods for controlling weeds in sugarcane have been used; some may be expensive,

painstaking, or infeasible either because of labor supply or adverse weather conditions. Mechanical operations can only smother the weeds between the rows of sugarcane and weeds are left uncontrolled within the crop-row. Use of chemicals, or herbicides, for controlling weeds in sugarcane was introduced about three decades ago to overcome the problems associated with other methods of weed control. Control of weeds with herbicides has become popular in the last two decades. Some materials are effective in controlling broadleaf weeds in sugarcane with little to no effect on grassy weeds. Since sugarcane also is a grass, the similarity in morphology of this crop plant and grassy weeds requires careful selection and intensive evaluation of herbicides to control effectively the grass weeds without sugarcane injury.

This research was designed to develop suitable measures using atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and ametryne (2-ethylamino-4-isopropylamino-6-methylthio-s-triazine) in combination with various surfactants for control of two annual grassy weeds: Alexandergrass (Brachiaria plantaginea (Link) A. Hitchc.) and broadleaf panicum (Panicum adspersum Trin.) in sugarcane. These two annual grasses are major problems in sugarcane production on the organic soils of south Florida.

LITERATURE REVIEW

Sugarcane is grown under differing climatic, cultural and soil regimes on small holdings, traditional plantations and extensive mechanized farms in tropical and subtropical regions. Sugarcane management programs should include practices for optimum plant stands and growth during favorable environmental periods to enhance crop competition against weeds and to maximize recoverable sugar yields.

Weeds contribute to losses or additional cost in sugarcane production in several ways: (a) yield reductions due to weed competition; (b) cost of herbicide, labor, and equipment for controlling weeds; (c) yield reductions due to possible herbicidal injury; and (d) yield reductions and extra cost due to miscellaneous factors such as weed trash at harvest, vines that break stalks and interfere with efficient mechanical harvesting, and insect pests and vectors that live on weeds. The extent of losses range from slight to severe depending upon the type of weeds, degree of infestation, and period of competition. Winter weeds reduced yields of sugarcane in Louisiana even though they grew abundantly for only a few weeks and were removed 8 months before harvest (Millhollon 1970a). In Louisiana, heavy johnsongrass (Sorghum halepense (L.) Pers.) infestations in ratoon sugarcane reduced yields from 25 to 50% below a

handweeded check (Millhollon 1970b). Vectors that transmit mosaic, a serious viral disease of sugarcane in Louisiana, are known to live on weeds in or near sugarcane fields (Pemberton and Charpentier 1969). Millhollon (1971) reported that winter weeds, burclover (Medicago hispida Gaertn.), and chickweed (Stellaria media (L.) Cyrillo) were about equally competitive with sugarcane and both reduced stand and yield. The degree of reduction depended on the date of weed removal. Sugarcane infested with weeds until February 15 or March 15 had approximately 17 and 42% fewer shoots per acre on May 15, respectively, than sugarcane maintained weedfree. In spring-planted sugarcane on loamy soils of medium fertility in India, number of shoots and millable cane and sugar yields were reduced in unweeded check plots due to competition for moisture between crop and weeds in the hot summer months of May and June (Choudhary and Mani 1974). Handweeding of ratoon sugarcane, heavily infested with crabgrass (Digitaria sanguinalis (L.) Scop.), required 125 manhours in mid-May or 150 manhours per hectare 2 weeks later. The delay in weeding was accompanied by a 20% decrease in sugar yield (Orsenigo 1970).

Specific weed competition varies. Yellow nutsedge (Cyperus esculentus L.) control has high priority in South Africa (Gosnell 1965) while the advantages of purple nutsedge (Cyperus rotundus L.) control in Hawaii do not appear to justify the expense. Nearly total weed control is required for 4 to 5 months before Hawaiian sugarcane closes in

(Hilton 1967). Three to five months elapse between planting or harvest and layby in Florida. Slow cane growth in cold weather or damaging freezes may extend this period to 6 to 8 months. Highest sugar yields were obtained with 3 to 6 weeks of handweeding or herbicidal weed control in Taiwan (Peng and Sze 1969). Weed control in Trinidad is needed from crop emergence until primary shoots are above ground, approximately the third through the twelfth week after planting. Unchecked weed infestations beginning 3, 6, and 9 weeks after planting in Trinidad reduced cane and sugar yield significantly (Lamusse 1965). Dense johnsongrass infestations in Louisiana can reduce yields by 25%. Peng and Lian (1974) reported that torpedograss (Panicum repens L.) reduced the cane yield proportional to the weight of rhizomes until it reached a maximum of 50% when rhizomes were present at about 5 tons/a. Weeds in the crop furrow reduced sugar yields more than 50% in Taiwan.

Sugarcane regions have different ecological conditions and different weed problems, although many of the world's cane plantations are plagued with the same or related weeds. It is likely that the early, vigorous competitors noted in Trinidad will occur consistently (Richardson 1963). Holm (1969) listed the world's 10 worst weeds. Out of them, the following six have been reported important to sugarcane culture: bermudagrass (Cynodon dactylon (L.) Pers.), johnsongrass, guineagrass (Panicum maximum Jacq.), cogongrass (Imperata cylindrica (L.) Beauv.), goosegrass

(Eleusine indica (L.) Gaertn.), and purple nutsedge. Another listing included four of the above species but also adds the following frequent upland weeds: paragrass (Brachiaria purpurascens (Raddi) Henr.), torpedograss, paspalum (Paspalum conjugatum Bergius), sensitive plant (Mimosa pudica L.) and purslane (Portulaca oleracea L.) (Saiki et al. 1967). Other widely distributed weeds of importance in fewer cane areas are yellow nutsedge, giant sensitive plant (Mimosa invisa Mart.), itchgrass (Rottboellia exaltata L.f.), and witchweed (Striga lutea Lour.). Numerous universal species including crabgrass, dayflower (Commelina spp.) and others infest sugarcane fields. Annuals are more readily controlled than the perennials and more hardy annuals mentioned above. Weeds which originate from vegetative propagules may be extremely difficult to control.

Various mechanical, cultural, and chemical methods have been developed to control weeds in sugarcane, and a review of the literature concerning each is presented.

Mechanical and Cultural Practices

Intensive plowing, disking, and cultivation of fallow fields is effective in destroying vegetatively propagated perennials as well as annual weeds. Mechanical operations must be timely and cannot interfere with appropriate soil management practices. Mechanical tillage such as ridge-breaking and soil moving can induce cultural responses. In Louisiana, moving soil to the cane drill early in April reduced the number of tillers as compared to late-April

"dirting." But, the yield of sugarcane was unaffected due to apparent compensation in stalk weight (Hebert and Matherne 1963).

Flooding of sugarcane fields between crops has been practiced for many years in Guyana (Follette-Smith 1939). Submersion controls some weed species, but little supporting evidence has been advanced (Bates 1957) except for johnsongrass in Louisiana (Arceneaux et al. 1952). Leaf-trash mulch from a 100 metric tons/ha crop can provide good weed control in a ratoon (Thompson 1966). A crop of white sweetclover (Melilotus alba Desr.) plus fallow land preparation and herbicides in sugarcane have been proposed as a johnsongrass control system (Farwell 1961).

Chemical Weed Control

Chemical control of weeds is a relatively new approach to suppress weeds for economic crop production. It is based on chemical selectivity, the differential tolerance of plants to applied chemicals. Herbicides are applied either preemergence or postemergence for controlling weeds in sugarcane. Preplanting incorporation of herbicides in sugarcane is not common.

Preemergence Herbicides

The use of preemergence herbicides for controlling weeds in sugarcane is quite common and effective. Preemergence application of 2 kg/ha atrazine in 1000 L/ha of water was most effective in controlling heliotrope (Heliotropium eichwaldii L.), heartleaf cocklebur (Xanthium

strumarium L.), horse purslane (Trianthema monogyna L.), and barnyardgrass (Echinochloa crus-galli (L.) Beauv.) in spring-planted sugarcane (Choudhary and Mani 1974). A mixture of simazine (2-chloro-4,6-bis (ethylamino)-s-trazine) and 2,4-D (2,4-dichlorophenoxy acetic acid) at 2 kg/ha each preemergence followed by one cultivation, gave the best suppression of purple nutsedge while the overall best weed control and highest cane and sugar yields were obtained by 2 kg/ha atrazine preemergence. Atrazine was also the most profitable treatment (Choudhary et al. 1971). Preplant incorporated application of vernolate (S-propyl dipropyl-thiocarbamate) at 0.3 kg/ha and EPTC (S-ethyl dipropylthio-carbamate) at 0.45 kg/ha gave fairly good control of purple nutsedge, crabgrass (Digitaria adscendens (H.B.K.) Henr.) and some broadleaf weeds and remained active for a long time despite heavy rainfall (Ikeda 1970).

Preemergence weed control treatments with terbacil (3-tert-butyl-5-chloro-6-methyluracil) at 1.8 kg/ha and fenac (2,3,6-trichlorophenylacetic acid) at 5.0 kg/ha were compared to a mixture of TCA (trichloroacetic acid sodium) 11 to 19 kg/ha plus silvex (2-(2,4,5-trichlorophenoxy) propionic acid) at 3.4 kg/ha. Terbacil did not injure either cultivar, but fenac injured both CP52-68 and L60-25 enough to reduce the yield of sugar in the plant crop by about 10% as compared to the TCA + silvex control (Matherne and Millhollon 1973).

Simazine at 3.95 kg/ha and TCA (sodium) at 10 kg/ha with or without added 2,4-D at 4 kg/ha were used as pre-emergence herbicides in plant cane and later applied to the first ratoon. No treatment had any phytotoxic effect; simazine gave the highest yield and net profit (Patro and Tosh 1972). Alachlor (2-chloro-2,6-diethyl-N-(methoxymethyl)acetanilide)+2,4-D was most effective herbicide mixture for preemergence grass control in Natal soils, but it did not control nutgrass (nutsedge) and water grass (Cyperus spp.) (Richardson 1971). Atrazine, ametryne, simazine, prometryne (2-methylthio-4,6-bis(isopropylamino)-s-trizine), desmetryne (2-(isopropylamino)-4-(methylamino)-6-(methylthio)-s-triazine), and 2,4-D (sodium salt) at 3.82 kg/ha were applied preemergence in sugarcane. Simazine, atrazine and prometryne provided 88.2, 87.5 and 68.8% weed control, respectively, with improved crop germination at 90 days after spraying. All treatments increased the millable cane yield (Singh et al. 1970).

Postemergence Herbicides

Postemergence application of herbicides has been effective in controlling weeds in sugarcane. Postemergence herbicides have relatively high foliar activity. The effect of some herbicides is reviewed in this section.

Atrazine at 1.25 to 2.50 + 2,4-D ester formulation at 1.0 kg/ha applied postemergence 35 days after planting sugarcane gave very good control of purple nutsedge and broadleaf weeds and increased cane height, number of

millable canes, and the cane yield compared with an unweeded control (Gill and Singh 1972). No deleterious effects were observed in early use of 2,4-D for weed control in sugarcane. Seedpiece germination was delayed and three applications of 3 kg/ha 2,4-D reduced cane yield by 9% (Arceneaux 1948). Stalk bending and breakage has accompanied 2,4-D application (Nolla 1950). Topically applied isopropyl ester and triethanolamine salts of 2,4-D at about 2.4 kg/ha reduced growth when applied to 1-month-old cane. Lower dosage rates applied to 2-month-old cane plants were safe (Havis 1953). These few instances apparently represent unusual circumstances. Herbicide rates of 2,4-D are considered safe for sugarcane although varieties may differ in susceptibility.

In Mexico, postemergence application of ametryne, atrazine, and several combinations of these two herbicides had a stimulating effect on the yield of cane and sugar per hectare. Maximum increase in yield was obtained with 2 kg/ha of atrazine applied postemergence (Azzi and Fernades 1970). Richardson (1971) reported satisfactory control of nutsedge using ametryne or diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea) with 2,4-D. Postemergence application of atrazine at 1 lb + dalapon (2,2-dichloropropionic acid) 6 oz/a + 10% Sun 11E oil controlled both grassy and broadleaf weeds (Behrens and Miller 1970). Recent postemergence treatments in Florida include dalapon, atrazine, atrazine + 2,4-D + non-ionic surfactant, atrazine + 2,4-D + phytobland oil, ametryne, fenac + 2,4-D, and diuron or monuron

(3-(p-chlorophenyl)-1, 1-dimethylurea) + 2,4-D + surfactant. Ametryne and dalapon are recommended only for directional application off the cane foliage (Orsenigo 1969).

Postemergence application of Asulox-60 (asulam, methylsulfanilylcarbamate) + Actril-D (ioxynil, 4-cyano-2,6-diiodophenol) to 2 to 4 month cane at rates of 5.6 + 2.8 and 8.4 + 4.2 L/ha gave excellent weed control without noticeably affecting cane yield or quality, while Asulox-60 alone failed to control certain broadleaf weeds and sedges (Goberdhan 1973). Asulam at 2 lb/a has given satisfactory control of many of the grass pests of Florida sugarcane when applied at the 2 to 4 leaf-stage of grass development and before extensive tillering has taken place. Asulam is well tolerated by sugarcane and broadcast applications are feasible under most conditions (Knobel and Crowley 1972). Millhollon (1976) has reported that asulam at 3.3 or 4.5 kg/ha gave 54 and 61% johnsongrass control, respectively, when applied only to the initial infestation in sugarcane. Degree of control was increased to 81 and 88% when application was repeated to the regrowth. Both single and dual asulam treatments produced yields of sugar that were about double the yield of an untreated check and about 90% of the yield of a hand-weeded check. Millhollon (1970b) also reported that organic arsenicals like MSMA (monosodium methanearsonate) could be potential herbicides for perennial infestants like johnsongrass in sugarcane.

Herbicide Mixtures and Additives

In recent years, the use of additives with herbicides has drawn the attention of research workers. Surfactants increase wetting ability as they reduce surface tension and contact angle of the spray on the plant surface. They also reduce the rate of evaporation allowing a longer retention of the spray in liquid form on a plant surface which permits higher rate of absorption (Burt 1973). Surfactants and other additives influence the phytotoxicity of herbicides (Foy and Smith 1969; McWhorter 1963a; McWhorter 1963b; Smith et al. 1967; Foy et al. 1967; Burr and Warren 1971). Adjuvants are used to reduce surface tension (Foy and Smith 1965) and enhance cuticular penetration (Foy 1964; Szabo and Buchholtz 1961).

Almodovar-Vega and Ilnicki (1970) reported enhanced atrazine activity in controlling crabgrass and yellow foxtail (Setaria lutescens (Weigel) Hubb.) using non-phytotoxic oil and adjuvants. Best grass and broadleaf weed control was obtained by preemergence application of atrazine and oil as compared to atrazine alone or other herbicides. Chandler and Santelmann (1970) reported that excellent postemergence control of prickly sida (Sida spinosa L.) was obtained by chloroxuron (3-(p-(p-chlorophenoxy) phenyl)-1, 1-dimethylurea), C-6313 (N-(4-bromo-3-chlorophenyl)-N-methoxy-N-methylurea) and atrazine in combination with surfactants or oil. Activity of linuron (3-(3,4-dichlorophenyl)-1-methylurea) and prometryne was improved by surfactants. The

most successful treatments in controlling copperleaf (Acalypha ostryaefolia Ridd.) were postemergence applications with either prometryne with surfactants or atrazine with oil. Excellent control of morningglory (Ipomoea lacunosa L.) was also provided by atrazine plus oil. Transpiration rate in corn (Zea mays L.) and soybean (Glycine max (L.) Merr.) following treatment with atrazine was reduced by the addition of phytobland petroleum oils to the treatment solutions. Oil type and viscosity did not significantly affect transpiration (Coats and Foy 1974a). In a separate study Coats and Foy (1974b) also reported that paraffinic and naphthenic phytobland oils used as adjuvants markedly enhanced the foliar uptake and acropetal translocation of ring-labeled atrazine by corn. In maize, Synergid-3 (a non-phytotoxic additive synthesized from isoparaffins, esters of alkyl-phosphoric acid, and alkyl-polyglycol ether) improved the effect of postemergence application of atrazine against couchgrass (Agropyron repens (L.) Beauv.) (Kees and Hoyos 1972).

Synergistic responses to atrazine in combination with other herbicides have been reported (Lynch et al. 1970). Messersmith and Nalewaja (1969) reported that oil at 775 ppmw increased atrazine activity synergistically. On high organic medium to fine-textured soils, postemergence application of atrazine at 2 lb/a + 10% v/v oil gave slightly more consistent weed control than preplant or preemergence atrazine at 3 lb/a. Nalewaja (1968) reported that linseed

and sunflower oil with atrazine gave better control of grassy weeds than atrazine and petroleum oil. Improved atrazine activity was reported (Newton 1969) by adding cacodylic acid (hydroxydimethylarsine oxide) and the combination was non-toxic to conifers. Atrazine at 1 lb + dalapon 0.5 lb/a + Sun Oil 11E 3% v/v was not phytotoxic to corn 4 or 12 inches high and controlled giant foxtail (Setaria faberi Herrm.) at early growth stages (Parochetti 1970). Several oils used as 5% oil/water emulsions increased the herbicidal activity of atrazine on green foxtail (Setaria viridis (L.) Beauv) and shattercane (Sorghum bicolor (L.) Moench) as compared to atrazine in water alone or with 0.1% (v/v) wetting agent (Peacock 1970). Russ and Feltner (1968) reported satisfactory control of grassy weeds in corn using 2 to 3 lb atrazine + 1 to 2 gal nonphytotoxic oil in 20 to 30 gal/a total spray. Schrader and Meggitt (1970) reported increased penetration of atrazine through leaf surfaces using oil/water emulsions as wetting agent before and after treatment application. Strand (1969) observed 20 and 40 fold greater phytotoxicity on giant foxtail and redroot pigweed (Amaranthus retroflexus L.), respectively, from the use of an effective adjuvant with foliage-applied atrazine.

The presence of 1% (v/v) surfactant in dalapon solutions increased johnsongrass control above that of dalapon alone. Addition of 0.1 M potassium dihydrogen phosphate ($K H_2P O_4$) + surfactant was more beneficial than surfactant alone in

increasing dalapon toxicity to johnsongrass. (McWhorter and Jordan 1976).

Increased herbicidal activity of bentazon (3-isopropyl-1H-2,1,3-benzothiadiazine-4-(3H)-one 2,2-dioxide) in controlling redroot pigweed was reported by adding emulsifiable linseed oil and petroleum oil (Nalewaja et al. 1975). Oils have been shown to influence the effectiveness of post-emergence herbicides by: (1) modifying the cuticle to permit greater herbicide uptake (Bandeen 1969; Barrentine and Warren 1970; Saunders and Lannecker 1967); (2) by functioning as solvents for the herbicide to increase the rate and period of uptake (Burr and Warren 1971); or (3) by increasing spray retention (Nalewaja 1972).

Nalewaja and Adamczewski (1976) reported that the loss of atrazine from metal planchets was decreased by an increase in dosage applied and linseed oil additive. Vapor loss from plant surfaces depended on the plant species and other factors. Increased absorption and translocation of dicamba (3,6-dichloro-o-anisic acid) with additives has been reported by Addink and Nalewaja (1972) in spurge (Euphorbia spp.). Atrazine at 1.5 lb/a + adjuvants gave excellent broadleaf weed control but control of grasses was not satisfactory (Wilson and Ilnicki 1968; Hatfield and Sweet 1973). Increase in activity of cyanazine (2-chloro-4-(1-cyano-1-methylethylamino)-6-ethylamino-s-triazine) has been reported by the addition of either surfactants or nonphytotoxic oil (Lee and Alley 1972; Kern et al. 1975). Improved activity

of diuron, linuron and bromacil (5-bromo-3-sec-butyl-6-methyluracil) with surfactants was reported when applied as foliar spray to weeds (Hill et al. 1965). Bayer (1972) reported that optimum surfactant concentration for improving wettability ranged from 0.01 to 0.1% v/v although concentrations required for maximum herbicide activity were around 0.2 to 0.5% for chlorophenoxy compounds and 0.5 to 1.0% for most other foliar-acting compounds.

Climate and Herbicides

Climatic conditions have been reported to affect the activity of herbicides. Barban (4-chloro-2-butynyl-m-chlorocarbanilate) herbicidal action was increased by cold temperatures following application (Neidermyer and Nalewaja 1969). Dicamba (Behrens 1967), 2,4-D (Elle 1952) and DSMA (disodium methanearsonate) (Rumberg et al. 1960) were more active at high temperatures than at low temperatures. Difference in temperature altered the uptake and translocation of simazine (Sheets 1961) and terbutryne (2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine) (Dudek et al. 1973). Clor et al. (1962) and Prasad et al. (1967) demonstrated that the movement of 2,4-D and dalapon was enhanced when plants were subjected to high relative humidity (RH). They suggested that high RH increased herbicide absorption through hydrated cuticles and increased translocation of the herbicides both basipetally and acropetally in the plants.

McWhorter and Jordan (1976) reported that johnsongrass control with dalapon at 1.12 kg/ha was decreased as air temperature increased from 16 to 27 to 38 C. Plants at 16 and 27 C with 100% RH were more susceptible to dalapon than at 35% RH. Addition of surfactant increased johnsongrass control at 27 and 38 C regardless of RH. Adding 1% v/v surfactant and maintaining plants at 100% RH at 38 C temperature resulted in a significant reduction in johnsongrass control than 35% RH and 38 C. Bentazon gave increased red root pigweed control with high rather than low humidity. However, the increased weed control with high humidity was greater at 10 C than at 20 or 30 C (Nalewaja et al. 1975). The detrimental effect of low humidity was reduced by the addition of emulsifiable linseed oil in bentazon.

MATERIALS AND METHODS

These experiments were conducted at the Agricultural Research and Education Center (AREC), Institute of Food and Agricultural Sciences, University of Florida at Belle Glade except for laboratory work in the Department of Chemical Engineering at the University of Florida in Gainesville. Belle Glade is located in Palm Beach County near the southern-most tip of Lake Okeechobee in south Florida at 26.40 N latitude, 80.44° W longitude, and an altitude of about 3.66 m above sea level.

The normal annual rainfall for this area is about 150 cm. Nearly 60% of this total occurs during the "rainy" season of June through September. The remaining 40% is distributed over the other 8 months with less than 10% falling in December, January, and February. The highest yearly rainfall recorded since 1924 was 215 cm in 1947 and the lowest was 85 cm in 1967. Yearly average maximum and minimum temperatures are about 28 C and 16 C, respectively. Freezing temperatures occur an average of twice a year. The lowest temperature ever recorded at the Center was -4.5 C in 1940 and the highest was 37.8 C in 1931. Average monthly temperatures, rainfall, and relative humidity data for the experimental period from January 1975 through June 1976 are presented in the appendix (I).

This research required a series of experiments in the laboratory, growth chambers, greenhouse, and field. The procedures are described separately. All application rates of herbicides are expressed on active ingredient basis and surfactant concentrations as percent v/v. An untreated control treatment was maintained in all experiments.

Laboratory Experiments

The parameters studied in the laboratory were surface tension and contact angle for various combinations of water, surfactants, and herbicides. The surfactants included were Triton B-1956 (modified phthalic glycerol alkyd resin), Span-20 (sorbitan monolaurate), Surfactant-WK (dodecyl ether of polyethylene glycol), Triton X-114 (octyl phenoxy polyethoxy ethanol), Ortho X-77 (alkylarylpolyoxy ethlene glycol), Sterox-NJ (alkyl phenol ethylene oxide), and Tween-20 (polyoxyethylene sorbitan monolaurate). All surfactants were nonionic. The herbicides were commerical 80% wettable powder formulations of atrazine and ametryne. Sun Oil 11E was included in the study in addition to the above surfactants. All observations were recorded at a room temperature of 25 C.

Preparation of Solutions

Solutions were prepared separately for each series of measurements. All surfactants and Sun Oil 11E were tested in distilled water (DW), tap water (TP), and synthetic hard water of 250, 500, 750 and 1,000 ppm Ca ions. The tap water hardness was approximately 90 to 100 ppm. Synthetic water

hardness was developed by adding $CaCl_2$ to distilled water. Stock solutions of 2% of surfactants and Sun Oil 11E were prepared and then diluted to 1, 0.5, 0.25, 0.125, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, and 10^{-5}% by volume (v/v). Each sample was used to measure both surface tension and contact angle. Each measurement was repeated once and the average values of two readings were recorded.

In the second series of experiments, atrazine and ametryne solutions were prepared using 2.67, 5.34, and 10.68 g/L of distilled water to simulate the application rates of 1, 2, and 4 kg/ha in 400 L/ha of water. The surfactants and Sun Oil 11E were added at concentrations of 0, 0.5, 1.0, and 2.0% (v/v). The same sample was used to measure surface tension and contact angle. Measurements were repeated once and the average values were recorded.

Surface Tension Measurement

A sample of 100 ml was drawn from the solution for surface tension measurement by Wilhelmy's detachment method using a "torsion balance" (O'Spiow 1972). The instrument was calibrated using double distilled water with a surface tension of 72.8 dynes/cm at 20 C and was confirmed by using ethyl alcohol with a surface tension of 22.0 dynes/cm. All observations were converted into dynes/cm. Each sample was measured twice and the average was recorded.

Contact Angle Measurement

A drop of solution was used to measure the contact angle with a contact goniometer on a clean and dry teflon

surface. The contact goniometer was calibrated with distilled water which has a contact angle of 108° on a teflon surface and confirmed with benzene which has a contact angle of 20° on a teflon surface. The uniformity in the size of drop was maintained by using a microsyringe of specific volume. The drop of solution was placed gently on the teflon plate and the horizontal and vertical axes were adjusted according to the shape of the drop and the contact angle was read directly. Contact angles were recorded from opposite sides of the drop and the average of both readings was recorded.

Growth Chamber Experiments

The experiments were conducted in four Sherer-Gillett Model 25HL Controlled Environmental Chambers. Each chamber was illuminated with 10 Sylvania F48T12l CS/VHO flourescent lamps, each rated for 6750 lumens plus eight Westinghouse 25-watt frosted tungsten bulbs.

Lights were programmed for illumination with tungsten bulbs only during the first and last hour of each day. Both tungsten and fluorescent illumination were provided for the remainder of the light period. A constant period of 12 hours of light was alternated with 12 hours of dark throughout the experimental period. Photoperiod was controlled by an automatic timer. Air circulation was vigorous from bottom to top through spreading vanes. Outside vents were open fully to permit outside air exchange.

Set Up and Calibration of Growth Chambers

The four growth chambers were programmed into four different groups, i.e. low temperature-low humidity, low temperature-high humidity, high temperature-low humidity, and high temperature-high humidity. The day and night temperatures and relative humidity levels were set up separately. Low temperature levels were 21.1 C during the day and 10 C at night. High temperature levels were 32.2 C in day and 15.6 C at night. The arrangement for each chamber is given in Table 1.

Table 1. Temperature and Relative Humidity for Growth Chamber Experiments

Chamber	Temperature (C)		Relative Humidity (%)	
	Day	Night	Day	Night
1. Low temperature and low relative humidity	21.1	10.0	40	80
2. Low temperature and high relative humidity	21.1	10.0	90	90
3. High temperature and low relative humidity	32.2	15.6	40	80
4. High temperature and high relative humidity	32.2	15.6	90	90

Temperatures were originally set manually with final calibration and control through plastic cam program disks attached to the temperature control and recording system. Temperatures inside the chambers were confirmed by internal thermometers. Humidity levels were maintained through wet bulb temperature control and levels inside the chambers were

confirmed by internal automatic recording hygrometers. To insure the accuracy of chamber calibration, units were operated for one week before each experiment was started.

Two experiments were conducted in the growth chambers. The herbicide treatments for both experiments were atrazine at 1.12 kg/ha, ametryne at 0.56 kg/ha and an untreated check. These treatments were applied to the sugarcane varieties, CP63-588 and CL41-223 in the first experiment and to two annual grasses, Alexandergrass and broadleaf panicum in the second experiment.

In the first experiment with sugarcane, a total of 96 pots were used; each chamber contained 24 pots (2 varieties, 3 treatments, and 4 replications). In the second experiment with grasses, only 72 pots were used; each chamber contained 18 pots (3 treatments and 6 replications).

Raising Plant Material

Healthy sugarcane stalks were cut into nodal pieces having a length of 2.5 cm on either side of the node. Single eye pieces of uniform length and thickness were selected, treated with 0.1% (w/v) solution of Benlate (benomyl methyl (1-butylcarbamoyl) benzimidazol-2-yl-carbamate) to protect the seed pieces from soil borne diseases, and planted in sterilized soil in metal flats. Sugarcane plants were allowed to grow for approximately 3 weeks at which time seedlings of uniform size and vigor were selected and transplanted in stainless steel pots in soil collected from two different locations. Soil from

A. Duda and Sons farm (A-7) was rich in broadleaf panicum seeds while soil obtained near Gove Elementary School was rich in Alexandergrass seeds. Both soils were used in a 50:50 ratio and mixed thoroughly. Each pot contained 1.4 kg. of soil. One sugarcane plant was put in each pot. Soil was packed carefully and irrigated. The pots were maintained in the greenhouse for one week for seedling establishment before transferring them to growth chambers.

For the second experiment with two grasses, 1.4 kg. of mixed soil was put in each pot and the pots were kept in the greenhouse for 10 days to establish uniform stands of both grasses from the natural seed population in the soil. After 10 days of growth, the pots were transferred to the growth chambers.

Application of Treatments

AAtrex-80W and Evik-80W, commercial wettable powder formulations, were used as the source of atrazine and ametryne, respectively. AAtrex-80W or Evik-80W was suspended in water to simulate application rates of 1.12 kg/ha of atrazine and 0.56 kg/ha of ametryne in 400 L of water. A power sprayer mounted on an experimental crawler tractor was used for spraying. The pots were removed from the growth chambers and arranged according to treatment in rows which were sprayed at a pressure of 2.12 kg/cm^2 using a multi-nozzle boom with 8003 tips in the center nozzles and 8002 on the boom ends. The speed of the tractor was maintained at 50.3 m/min. The pots were left in the sun for 2 to 3 hours after application for

drying and then were moved back to their respective chambers. In the first experiment, the treatments were applied when the height of sugarcane was approximately 30 cm and in the second experiment when the grasses were 8 to 10 cm tall.

Phytotoxicity Rating

The experiments were observed carefully after the application of treatments and phytotoxicity was recorded by visual observations. Phytotoxicity was evaluated on scorching and burning of leaves, wilting and twisting of plants, and reduction in height, number and weight of plants. Rating was started when the first symptoms became visible and was continued until phytotoxic symptoms were stabilized. A scale ranging from 1 to 10 was used for phytotoxicity rating; 1 indicated no phytotoxicity and 10 death.

Harvesting and Recording of Data

Plants were allowed to grow in the growth chambers for 30 days after treatment application. Fresh and dry weights of sugarcane tops and roots were recorded at harvest in the first experiment, and the total number of grasses present before and after the application of treatments in the second experiment. Sugarcane tops were clipped close to the soil surface and fresh weight was recorded immediately. Tops were dried at 50 C until constant weight was obtained. Sugarcane roots were taken out of the soil by gently washing over a screen, excess water was removed with paper towels, and fresh weight was recorded. Roots were dried at 50 C until constant weight was obtained.

Greenhouse Experiments

Four experiments were conducted in the greenhouse with CP63-588 variety of sugarcane. Various rates of application of atrazine and ametryne were tested separately and with different concentrations of individual surfactants on sugarcane and two annual grass species. The surfactants were Surfactant-WK, Span-20, Tween-20, and the combination of Span-20 and Tween-20 at 50:50 v/v basis. In the fourth experiment, surfactants were tested without atrazine and ametryne to determine phytotoxicity to sugarcane and grasses.

The procedures for raising sugarcane in flats, transplanting in pots, phytotoxicity rating, harvesting, and recording the data were the same as described under growth chamber experiments. A different procedure for treatment application was used in the greenhouse experiments.

Application of Treatments

The required amounts of herbicides and surfactants were weighed or measured accurately and solutions were prepared in 3.785 L of water. A hand sprayer with 3.785 L of tank capacity and a single nozzle boom was used to apply the treatments in all four experiments. CO_2 was used as a source of pressure and the sprayer was calibrated to discharge 400 L/ha at a pressure of 2.12 kg/cm^2 with one 8003E tip.

Field Experiments

The agroclimatic conditions were relatively homogeneous in laboratory, growth chambers, and greenhouse, and various

treatment combinations were tested under field conditions where uncontrolled soil and climate characteristics have significant effect on the growth of the crop and on the performance of chemical treatments (Hammerton 1967).

Three experiments were conducted on a well decomposed organic soil, two at AREC Field 3E5 and one at C. A. Thomas Farms on U. S. Highway 27 near Bean City. Soil samples taken at the AREC plot had the following nutrient analysis.

Table 2. Nutrient Status of Muck Soil

Nutrient	Amount (kg/ha)
Phosphorus	4
Potassium	84
Calcium	2430
Magnesium	1060
Sodium	130
Iron	195

The soil in the experimental field was a histosol, Terra Ceia muck (typic medisaprist, eumic, hyperthermic), black with 75% organic matter, 1.5% nitrogen, and a pH of 6.5. Soluble salt concentration was 392 ppm. The soil had field capacity of about 160% and consisted of well decomposed organic material; moderate fine and medium granular structure; friable, less than 5% fiber rubbed and unrubbed.

Field Layout

The first experiment was conducted as a split plot design with 18 treatment combinations consisting of nine herbicidal treatments as the main plot variable and two varieties as the subplot variable with six replications. Each of the 108 individual plots consisted of three rows 12.6 m in length at a spacing of 1.5 m. The whole experiment was divided into nine tiers with an alley 5 m wide beween tiers.

The second experiment was designed as a randomized complete block with 21 treatments and 6 replications. The other specifications were the same as in the first experiment.

The third experiment was a randomized complete block with 7 treatments and 6 replications. Row length and spacing were the same as in the first two experiments, but each plot was four rows wide. There were no alleys between replications.

Experiment No. 1 and No. 2

First and second experiments were conducted with plant cane while the third experiment was conducted in ratoon sugarcane. The first and second experiments at AREC were similar in field and management operations, and their details are described together. The only dissimilarities were planting dates, variety, and experimental design. The first experiment was planted on March 19, 1975 using CP63-588

and CL41-223 varieties while the second experiment was planted on December 5, 1975, using variety CP 63-588.

The fields were prepared by plowing, disking, and leveling. A blanket application of parathion EC (0,0-diethyl-0-p-nitrophenyl thiophosphate) at the rate of 4.0 kg/ha was disked in to control wireworms. An 0-6-45 fertilizer mixture with CuO 2%, B_2O_3 2% and ZnO 2% was applied broadcast at the rate of 450 kg/ha and disked into the soil. Furrows were opened across the field in a north-south direction at the distance of 1.5 m. The sugarcane stalks for seed were cut manually, laid in the furrows, and chopped into three-bud pieces. The seed pieces and open furrows were sprayed with diazinon (0,0-diethyl-0-2-isopropyl-4-methyl-6-pryimidyl thiophosphate) at the rate of 4.0 kg/ha to control wireworms. The furrows were covered, smoothed, and compacted by a roller. The fields became heavily infested with spiny amaranth (Amaranthus spinosus L.) and occasional crabgrass. A mixture of 2,4-DB (2,4-dichlorophenoxy butyric acid) and asulam was sprayed broadcast at 0.75 kg/ha and 2.0 kg/ha respectively in 400 L/ha of water. "Low Drift" at the rate of 0.25% v/v was added to reduce drift hazards. The water requirement for the crop was met by rainfall and water table control. The experimental field was surveyed and various weed species were collected and identified (Table 3.).

Table 3. List of Weeds Found in Experimental Field at Belle Glade AREC

	Scientific Name	Common Name
1.	Amaranthus spinosus L.	Spiny amaranth
2.	Ambrosia psilostachya DC.	Western ragweed
3.	Brachiaria plantaginea (Link) A. Hitchc.	Alexandergrass
4.	Chenopodium ambrosioides L.	Mexicantea
5.	Chenopodium album L.	Lambsquarter
6.	Commelina diffusa Burm. f.	Dayflower
7.	Cynodon dactylon (L.) Pers.	Bermudagrass
8.	Cyperus rotundus L.	Purple nutsedge
9.	Digitaria sanguinalis (L.) Scop.	Crabgrass
10.	Eleusine indica (L.) Gaertn.	Goosegrass
11.	Eupatorium capillifolium (Lam.) Small	Dogfennel
12.	Erechtites hieracifolia (L.) Raf.	American burnweed
13.	Geranium carolinianum L.	Carolina geranium
14.	Linaria canadensis (L.) Dumont	Blue toadflax
15.	Oxalis corniculata L.	Woodsorrel
16.	Panicum adspersum Trin.	Broadleaf panicum
17.	Parietaria floridana Nutt.	Florida pellitory
18.	Portulaca oleracea L.	Common purslane
19.	Ruellia caroliniensis (J.F. Gmel.)Steud.	Ruellia
20.	Salvia lyrata L.	Indian sage
21.	Sida acuta Burm. f.	Teaweed or ironweed
22.	Solanum nigrum L.	Black nightshade
23.	Sonchus asper (L.) Hill	Spiny sowthistle

Experiment No. 3

This experiment was conducted in a third ratoon crop of sugarcane variety CL41-223 at C. A. Thomas Farm in Bean City. The management operations were performed by the cooperator. The experimental period was April 1975 until April 1976.

Rodents were a major problem in field experiments and occasionally in the greenhouse. Poison baits containing zinc phosphide were applied as needed.

Application of Treatments

The treatments in Experiment 1 and 2 were applied at the appropriate stage of annual grass growth. Atrazine, ametryne, and surfactant solutions were prepared for 0.1 ha. All replications of a treatment were sprayed from the same tank mix at the rate of 400 L/ha in all experiments. A power sprayer with multinozzle boom, mounted on an experimental crawler tractor was used. The speed of the tractor was maintained at 3.0 km/hr with a boom discharge of 7.57 L/min. The boom carried 8003 nozzle tips with 8002 tips on both ends of the boom. Operating pressure was 2.12 kg/cm^2. All nine treatments in Experiment 1 were repeated in 6-week old regrowth in the ratoon crop. The treatments in Experiment 3 were applied using an AC 'G' tractor using oxygen as a source of pressure.

Observations

The observations were recorded at various stages of crop growth throughout the growing season. Plant counts

were started at emergence and were continued periodically until harvest. Periodic observations also were recorded on the height of cane stalks from the soil surface to the top visible dewlap (TVD), starting when crops were about 3 months old and continuing until harvest. Observations on phytotoxicity to sugarcane and weeds were recorded for the various treatments.

Harvesting

Sugarcane in the first experiment was harvested twice, first on February 12, 1976 when fully mature, and second on June 22, 1976, when the first ratoon crop was about 4 months old. The second experiment was harvested June 16, 1976 when the crop was about 6 months old. The third experiment was harvested at full maturity on April 7, 1976.

The weight of 10 random stalks from each plot, juice weight from 10 stalks, juice brix and polariscope readings were recorded at the time of harvesting after sampling 10 random stalks for juice analysis; the plots in the final experiment were burned to make the harvesting more efficient. The plots were harvested manually and millable sugarcane per plot was weighed with a load-cell mounted on a grab loader.

The first ratoon from the first experiment and the plant crop from the second experiment were harvested manually at 4 and 6 months of age, respectively, while green. Fresh weight was determined by a load cell mounted on a grab loader. Five stalks from each plot were chopped into small pieces and a composite sample was drawn to determine dry

matter content. The samples were dried at 50 C until constant weight was obtained.

Analysis of Sugarcane Juice

A sample of 2 L of juice was drawn from that extracted from 10 stalks from each plot and was used to determine brix and polariscope reading. Purity and sucrose content were calculated.

Brix (soluble solids in juice) was read directly by brix hydrometer and adjusted according to the temperature of the juice. Horne's dry lead method (Spencer and Meade 1945) was used to prepare the solution for the polariscope.

Sucrose percentage in sugarcane juice was calculated directly by degree brix and polariscope readings, using Schmitz's table (Spencer and Meade 1945). Sugarcane juice purity was calculated from brix and sucrose values using the following formula:

$$\text{Purity of Juice (\%)} = \frac{\text{Sucrose \% in Juice}}{\text{° Brix}} \times 100$$

Statistical Analysis

Treatments were randomized using Fisher and Yates (1957) tables of random numbers. Statistical analysis of the data was done on a Wang 2200 computer with programs based on the principles described by Steel and Torrie (1960) and Cochran and Cox (1968). Duncan's multiple comparison test was used for comparing means (Duncan 1965).

RESULTS AND DISCUSSION

Laboratory Experiments

Surface Tension

All surfactants and Sun Oil 11E reduced surface tension considerably at all concentrations (Tables 4 through 8). However, the lower concentrations had substantial effects as compared to higher concentrations. Surfactant concentrations ranging from 10^{-5} to 10^{-2} % were most effective in reducing the surface tension compared with 0% (DW). The additional reduction in surface tension from 10^{-2} to 2% was either very low or nil. This sharp decrease in surface tension by lower surfactant concentrations and slow reduction at higher surfactant concentration is noted because surfactant molecules align themselves randomly on the liquid surface with head (polar) up and tail (non-polar) down when small amounts of surfactants are added to a surfactant-free surface. Presence of surfactant molecules on the surface reduces surface tension. Reduction in surface tension continues with an increase in surfactant molecules until the whole surface is saturated with a monolayer of surfactant molecules. Surfactant molecules go under the monolayer because of unavailable space on the surface, and further reduction in surface tension does not occur if the addition of surfactant is continued. This concentration is called

Table 4. Surface Tension Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration (% v/v)	Surface Tension (dynes/cm)											
	Span-20						Tween-20					
	Water Hardness (ppm)						Water Hardness (ppm)					
	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	72.8	72.0	72.0	71.6	71.2	70.8	72.8	72.0	72.0	71.6	71.2	70.8
10^{-5}	72.2	66.7	47.6	53.0	47.8	38.1	68.8	69.0	69.5	70.3	69.5	69.3
10^{-4}	70.5	67.6	46.1	44.0	36.2	33.1	66.9	66.9	67.0	67.4	67.2	67.6
10^{-3}	48.8	47.6	41.5	36.4	31.2	29.3	52.0	51.8	52.2	52.6	53.3	54.1
10^{-2}	30.7	29.7	28.6	27.8	26.9	27.0	38.9	38.9	39.2	39.2	38.7	38.9
10^{-1}	29.7	29.3	28.6	27.6	27.2	26.9	37.3	37.7	37.3	38.9	38.1	37.9
0.125	29.7	29.1	28.2	28.0	27.0	26.7	36.8	36.8	37.3	38.1	38.1	37.9
0.25	29.7	29.3	28.0	28.4	27.2	2-.9	35.8	33.0	37.3	37.9	37.9	38.1
0.50	29.9	29.7	28.4	27.0	26.4	26.7	36.0	36.6	36.8	37.5	37.7	37.9
1.0	29.7	29.5	28.8	27.4	27.0	27.0	35.8	36.4	37.1	37.9	37.7	38.1
2.0	29.7	29.7	29.1	26.9	26.9	26.9	35.4	36.2	36.4	37.5	37.3	37.7

a. Distilled water

b. Tap water

Table 5. Surface Tension Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Surface Tension (dynes/cm)											
	Span-20 + Tween-20						Surfactant-WK					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	72.8	72.0	72.0	71.6	71.2	70.8	72.8	72.0	72.0	71.6	71.2	70.8
10^{-5}	71.4	68.2	59.8	58.2	57.4	54.5	58.1	56.8	56.8	57.1	58.1	62.1
10^{-4}	65.7	65.1	56.4	54.2	51.7	53.2	55.8	55.2	54.9	55.0	56.2	58.1
10^{-3}	51.5	48.2	46.9	49.2	46.4	47.3	50.9	51.8	51.8	51.8	51.8	53.0
10^{-2}	32.6	33.2	34.1	33.6	35.2	34.2	39.2	39.8	39.6	39.6	39.6	40.6
10^{-1}	30.4	31.1	31.2	32.4	31.8	31.2	27.0	27.4	28.2	27.0	27.6	29.3
0.125	30.1	30.4	31.1	32.1	30.9	30.2	26.7	26.9	27.0	26.9	27.0	26.7
0.25	29.8	30.1	30.4	29.3	31.0	29.9	26.7	26.9	27.0	26.9	27.0	26.5
0.50	30.0	30.1	28.2	28.4	30.2	30.0	26.5	26.5	27.2	26.7	26.7	26.9
1.0	28.9	29.8	29.1	30.0	30.1	29.8	26.5	26.7	26.9	26.5	26.9	26.9
2.0	29.8	29.1	30.1	29.1	31.2	28.2	26.5	26.7	26.5	26.7	26.5	26.7

a. Distilled water

b. Tap water

Table 6. Surface Tension Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Surface Tension (dynes/cm)											
	Ortho X-77						Sterox-NJ					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	72.8	72.0	77.0	71.6	71.2	70.8	72.8	72.0	72.0	71.6	71.2	70.8
10^{-5}	69.5	68.8	68.8	68.4	67.8	68.4	68.4	67.6	67.6	68.2	68.8	70.0
10^{-4}	58.5	57.7	57.5	57.3	56.8	57.0	64.6	63.2	63.8	63.2	63.2	63.0
10^{-3}	37.7	36.0	36.0	35.8	35.6	36.4	39.6	39.6	40.4	41.5	51.7	42.1
10^{-2}	32.2	32.2	31.8	31.6	31.4	31.8	32.2	32.0	32.4	32.2	32.4	32.4
10^{-1}	32.0	31.6	31.4	31.4	30.0	30.7	32.4	32.2	32.4	32.4	32.2	32.2
0.125	31.6	31.6	31.4	31.2	30.7	31.0	32.4	32.2	32.4	32.4	32.4	32.2
0.25	31.4	31.4	31.6	31.0	30.5	30.7	32.6	32.4	32.4	32.2	32.4	32.4
0.50	31.6	31.4	31.4	30.9	30.7	31.4	32.4	32.2	32.2	32.4	32.6	32.4
1.0	31.6	31.0	30.7	30.7	30.5	31.4	32.2	32.0	32.2	32.4	32.4	32.2
2.0	31.2	30.7	30.7	30.7	30.7	30.7	32.2	32.0	32.4	32.2	32.2	32.4

a. Distilled water

b. Tap water

Table 7. Surface Tension Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Surface Tension (dynes/cm)											
	Triton B-1956						Triton X-114					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	72.8	7.20	77.0	71.6	71.2	70.8	72.8	72.0	72.0	71.6	71.2	70.8
10^{-5}	71.8	70.7	68.5	66.9	56.8	56.4	67.4	67.4	67.6	68.6	69.1	70.5
10^{-4}	72.2	68.6	53.1	35.8	36.0	35.2	62.9	63.2	63.4	63.6	63.6	64.2
10^{-3}	45.1	44.2	35.8	31.2	31.4	29.5	48.2	48.4	49.0	49.7	50.1	51.0
10^{-2}	31.0	30.5	30.7	29.0	29.0	29.2	32.4	31.8	32.4	32.6	32.8	33.1
10^{-1}	30.3	29.7	29.7	29.1	28.8	29.0	30.3	29.9	29.9	29.7	30.3	30.3
0.125	30.1	29.7	29.3	29.0	28.8	29.0	30.1	29.9	30.1	30.5	29.9	29.7
0.25	29.7	29.5	29.7	29.3	29.1	29.5	29.5	29.9	29.3	29.5	29.7	30.1
0.50	29.9	29.7	29.1	29.1	28.8	29.1	29.7	29.3	29.9	29.7	29.7	29.7
1.0	29.7	29.3	28.8	29.0	29.0	29.1	29.7	29.5	29.3	29.3	29.5	29.7
2.0	29.9	29.5	28.8	28.8	28.8	29.0	29.1	29.3	29.3	28.8	29.5	29.7

a. Distilled water

b. Tap water

Table 8. Surface Tension and Contact Angle Responses to Sun Oil 11E Concentration and Water Hardness

Surfactant Concentration	Surface Tension (dynes/cm)						Contact Angle (°)					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	72.8	72.0	72.0	71.6	71.2	70.8	110	109	109	108	107	105
10^{-5}	57.5	57.0	58.1	58.9	58.3	57.5	75	75	76	76	74	74
10^{-4}	52.2	52.6	51.4	41.8	52.2	51.4	73	74	76	73	74	75
10^{-3}	47.4	47.8	48.2	49.0	48.6	48.4	71	71	73	74	75	74
10^{-2}	36.6	36.4	36.4	37.1	37.0	37.0	53	54	54	55	55	54
10^{-1}	33.0	32.8	33.0	32.8	32.8	32.6	51	50	50	50	50	49
0.125	32.4	32.6	32.8	32.6	32.4	32.2	50	51	48	48	50	48
0.25	32.6	32.6	32.6	32.2	32.6	32.2	49	48	49	49	48	49
0.50	32.4	32.6	32.6	32.4	32.6	32.4	47	48	48	47	48	50
1.0	32.6	32.4	32.6	32.2	32.6	32.6	48	48	51	47	50	48
2.0	32.4	32.2	32.4	32.6	32.6	32.6	48	48	48	49	49	49

a. Distilled water

b. Tap water

the critical micelle concentration (CMC). Additional surfactant causes micelle formation in liquid. The CMC varies from surfactant to surfactant depending upon its chemical composition. CMC for Span-20, Tween-20, Span-20 + Tween-20, Ortho X-77 and Sterox NJ was at about 10^{-2}% and for Surfactant-WK, Triton-l14 and Sun Oil llE it was at 10^{-1}%. Maximum and minimum reductions in surface tension (about 26.5 and about 36.0 dynes/cm) were recorded at 0.125% or higher for Surfactant-WK and 0.25% or higher for Tween-20. Water hardness ranging from 0 (DW) to 1,000 ppm as Ca ions did not seem to affect the surface tension except at the lower concentrations (10^{-4} and 10^{-5}%) of Triton B-1956 and Span-20 where a decreasing trend in surface tension with increasing water hardness was observed.

A mixture of Span-20 and Tween-20 was intermediate in terms of surface tension reduction at lower concentrations (10^{-5} to 10^{-2}%) but it was much closer to Span-20 at concentrations of 10^{-1}% or higher. Tween-20 was more effective at 10^{-4} and 10^{-5}% as compared to Span-20; however, the trend reversed at higher concentrations. Surfactants can be arranged in the following order on the basis of their effect on surface tension reductions: Surfactant-WK > Span-20 > Triton B-1956 > Triton X-l14 > Span-20 + Tween-20 > Ortho X-77 > Sterox NJ > Sun Oil llE > Tween-20.

Surface tension also was measured for the above surfactants and Sun Oil llE at 0.5, 1.0 and 2.0% concentrations in commercial wettable powder formulations of atrazine and

ametryne suspensions, simulating the application rates of 1.0, 2.0 and 4.0 kg/ha (Tables 9, 10 and 17). Atrazine solutions at 1.0, 2.0 and 4.0 kg/ha had considerably higher surface tension than the similar rates of ametryne, in the absence of surfactant and an increase in the rate of atrazine from 1.0 kg to 4.0 kg/ha reduced the surface tension from 57.0 to 41.7 dynes/cm while ametryne rates did not affect surface tension. This could be because of lower solubility of atrazine as compared to ametryne or presence of higher quantity of surfactant in the ametryne formulation. At higher rates, more atrazine particles remained in suspension and surface tension might have decreased due to the increase in viscosity of the suspension. Addition of surfactants to atrazine reduced surface tension considerably while addition of surfactants in ametryne solutions did not affect surface tension except with Surfactant-WK where reduction of about 5 dynes/cm was observed as compared to no surfactant. Addition of Tween-20 to ametryne solutions increased surface tension which could be due to the interaction between Tween-20 and the surfactant already present in ametryne formulation.

Contact Angle

Contact angle was determined for all the herbicide, surfactant, and water hardness combinations described in the previous section (Tables 8, 11 through 16 and 18). Addition of surfactants reduced contact angle. Increase in surfactant concentration from 10^{-5} to 10^{-1}% decreased contact

Table 9. Surface Tension Responses to Herbicide-Surfactant Combinations

Herb.	Rate (kg/ha)	No Surf.	Surf.-WK (%) 0.5	1.0	2.0	Span-20 (%) 0.5	1.0	2.0	Tween-20 (%) 0.5	1.0	2.0	Span-20+Tween-20(%) 0.5	1.0	2.0
						Surface Tension (dynes/cm)								
Atra.	1	57.0	28.6	28.6	28.6	29.5	28.8	28.6	39.4	39.8	38.7	34.5	35.2	34.6
Atra.	2	51.2	28.8	28.6	28.8	30.7	28.8	28.6	40.0	39.6	38.9	35.4	33.6	35.2
Atra.	4	41.7	28.6	28.8	28.6	32.4	30.5	28.8	39.6	39.2	39.0	34.2	33.8	34.1
Amet.	1	35.5	28.8	28.6	28.6	32.2	29.3	29.7	38.3	38.5	38.3	35.1	36.2	34.2
Amet.	2	33.3	28.8	29.0	28.8	32.4	30.3	30.3	38.3	38.5	38.3	34.2	33.9	35.1
Amet.	4	33.5	28.8	29.0	28.6	32.4	30.5	30.9	38.3	38.3	38.3	36.0	35.1	34.5

Table 10. Surface Tension Responses to Herbicide-Surfactant Combinations

Herb.	Rate (kg/ha)	No. Surf.	Ortho X-77 (%) 0.5	1.0	2.0	Sterox NJ (%) 0.5	1.0	2.0	Triton B-1956 (%) 0.5	1.0	2.0	Triton X-114(%) 0.5	1.0	2.0
						Surface Tension (dynes/cm)								
Atra.	1	57.0	32.2	31.8	31.6	32.8	31.8	31.8	33.1	33.0	32.8	30.7	30.3	30.1
Atra.	2	51.2	32.0	32.0	31.2	32.2	31.6	32.2	33.5	33.1	32.6	30.7	30.9	30.7
Atra.	4	41.7	31.8	32.0	32.0	32.6	31.6	32.0	33.5	33.3	32.4	30.5	30.5	30.7
Amet.	1	35.5	32.4	31.8	32.4	32.0	32.2	31.6	32.4	33.3	32.2	30.7	30.7	30.5
Amet.	2	33.3	31.8	31.8	32.0	32.4	32.0	31.4	32.6	33.1	32.2	30.7	30.7	30.7
Amet.	4	33.5	32.4	32.0	31.8	32.0	31.8	31.6	32.6	33.3	32.2	30.7	30.9	30.7

Table 11. Contact Angle Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Contact Angle (°)											
	Span-20						Tween-20					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	110	109	109	108	107	105	110	109	109	108	107	105
10^{-5}	103	99	78	72	65	65	104	104	105	105	104	104
10^{-4}	96	95	69	68	64	60	92	91	91	91	91	93
10^{-3}	73	69	65	60	55	54	83	81	83	84	84	85
10^{-2}	61	56	56	52	52	52	74	74	75	75	75	75
10^{-1}	61	57	56	54	53	52	72	72	71	72	72	71
0.125	58	56	55	52	51	51	70	70	71	70	71	72
0.25	59	56	51	52	51	51	68	68	70	69	70	70
0.50	59	57	55	54	53	52	69	68	69	68	70	70
1.0	60	68	56	55	54	52	68	68	70	70	70	69
2.0	59	55	51	51	52	52	67	68	70	72	71	71

a. Distilled water

b. Tap water

Table 12. Contact Angle Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Contact Angle (°)											
	Span-20 + Tween-20						Surfactant-WK					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	110	109	109	108	107	105	110	109	109	108	107	105
10^{-5}	102	100	98	96	89	86	92	93	93	94	95	97
10^{-4}	94	96	84	81	79	80	89	89	88	87	91	93
10^{-3}	79	77	78	74	69	67	81	81	80	82	82	85
10^{-2}	72	71	73	73	74	72	76	75	77	77	76	77
10^{-1}	65	61	60	59	55	57	41	42	44	41	43	45
0.125	64	58	56	54	57	58	40	41	41	41	41	42
0.25	58	56	52	53	54	52	39	41	41	40	41	41
0.50	55	54	53	56	55	53	40	39	40	39	39	42
1.0	54	53	52	54	56	51	38	39	40	40	41	40
2.0	52	53	51	52	51	51	39	39	40	40	40	40

a. Distilled water

b. Tap water

Table 13. Contact Angle Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Contact Angle (°)											
	Ortho X-77						Sterox-NJ					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	110	109	109	108	107	105	110	109	109	108	107	105
10^{-5}	90	85	84	81	80	82	96	95	96	96	95	96
10^{-4}	78	76	75	74	76	75	91	91	91	88	89	88
10^{-3}	67	65	64	61	61	62	70	71	70	71	72	75
10^{-2}	63	55	54	55	55	56	48	50	48	48	48	49
10^{-1}	61	53	52	54	55	54	48	47	49	49	48	48
0.125	60	52	51	59	52	54	48	50	48	47	50	50
0.25	58	51	50	51	51	52	49	49	47	48	50	50
0.50	51	51	51	51	50	51	48	46	48	49	49	49
1.0	51	50	50	50	49	52	47	49	50	49	48	48
2.0	50	57	50	50	48	49	46	46	45	47	49	49

a. Distilled water

b. Tap water

Table 14. Contact Angle Responses to Surfactant Concentration and Water Hardness

Surfactant Concentration	Contact Angle (°)											
	Triton B-1956						Triton X-114					
	Water Hardness (ppm)						Water Hardness (ppm)					
(% v/v)	DW[a]	TW[b]	250	500	750	1000	DW[a]	TW[b]	250	500	750	1000
0	110	109	109	108	107	105	110	109	109	108	107	105
10^{-5}	97	97	74	85	74	65	96	96	95	96	96	98
10^{-4}	99	76	76	48	52	48	91	91	92	93	92	94
10^{-3}	72	70	64	57	56	45	78	76	75	72	75	77
10^{-2}	61	60	60	52	52	46	57	56	59	61	62	62
10^{-1}	60	58	56	51	50	46	54	53	54	54	55	55
0.125	58	57	56	50	52	46	53	52	54	53	52	53
0.25	56	56	55	52	51	44	52	52	51	51	52	54
0.50	57	56	53	52	50	43	51	50	51	51	51	51
1.0	56	54	54	50	52	45	50	50	49	50	50	51
2.0	55	55	53	52	51	43	49	51	50	51	52	51

a. Distilled water

b. Tap water

Table 15. Contact Angle Responses to Herbicide-Surfactant Combinations

Herb.	Rate (kg/ha)	No. Surf.	Contact Angle (°)											
			Surf.-WK(%)			Span-20(%)			Tween-20(%)			Span-20+Tween-20(%)		
			0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0
Atra.	1	59	35	36	35	64	65	65	76	76	75	68	69	69
Atra.	2	83	36	35	35	63	64	65	77	74	75	67	68	68
Atra.	4	93	36	35	35	64	64	65	77	76	76	69	68	69
Amet.	1	58	37	35	35	62	63	62	76	75	73	64	65	66
Amet.	2	62	36	36	35	62	62	61	77	78	76	56	66	65
Amet.	4	65	35	35	35	64	62	62	74	74	73	67	66	65

Table 16. Contact Angle Responses to Herbicide-Surfactant Combinations

Herb.	Rate (kg/ha)	No Surf.	Contact Angle (°)											
			Ortho X-77(%)			Sterox NJ(%)			Triton B-1956(%)			Triton X-114(%)		
			0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0
Atra.	1	59	54	55	54	60	59	58	41	35	33	49	46	47
Atra.	2	83	54	52	53	58	59	60	40	36	32	50	49	50
Atra.	4	93	56	54	55	60	57	60	41	39	33	50	50	50
Amet.	1	58	56	56	57	60	59	58	40	34	32	51	50	50
Amet.	2	62	55	54	56	60	60	59	41	36	33	51	50	51
Amet.	4	65	55	55	55	58	58	58	41	37	31	50	50	50

Table 17. Surface Tension Responses to Herbicide - Sun Oil 11E Combinations

Herbicide	Rate (kg/ha)	Surface Tension(dynes/cm) Sun Oil 11E Concentration (% v/v) 0	0.5	1.0	2.0
Atrazine	1	57.0	36.4	33.1	32.6
Atrazine	2	51.2	41.7	34.5	34.5
Atrazine	4	41.7	42.5	35.2	35.0
Ametryne	1	35.5	34.9	34.5	34.5
Ametryne	2	33.3	35.0	34.5	34.7
Ametryne	4	33.5	34.3	34.3	34.5

Table 18. Contact Angle Responses to Herbicide - Sun Oil 11E Concentrations

Herbicide	Rate (kg/ha)	Contact Angle (°) Sun Oil 11E Concentration (% v/v) 0	0.5	1.0	2.0
Atrazine	1	59	45	46	46
Atrazine	2	83	50	49	46
Atrazine	4	93	52	52	48
Ametryne	1	58	56	52	51
Ametryne	2	62	54	51	50
Ametryne	4	65	55	52	52

angle sharply. After the CMC was reached, further decrease was either small or nil. The contact angle is basically a function of surface tension. Higher values of the contact angle were recorded from solutions having higher surface tension, and vice-versa. Maximum and minimum reduction in contact angle (40° and 70°) were obtained at 0.25% or higher concentration of Surfactant-WK and 0.125% or higher concentration of Tween-20, respectively. The contact angle without surfactant varied from 105 to 110°. Water hardness from 0 ppm (DW) to 1,000 ppm as Ca ions did not seem to affect the contact angle except at lower concentration (10^{-5} to 10^{-3}%) of Span-20, Span-20 + Tween-20, and Triton B-1956. Reduction in surface tension reduces the pulling force on the surface of the drop; the drop thereby tends to become flatter, consequently reducing the contact angle which provides more wetting of the plant surface by a given drop of liquid.

In the absence of surfactant, wettable powder formulation of atrazine solutions had higher contact angle than wettable powder formulation of ametryne. There was an increase in contact angle with an increase in the rates of application (1 to 4 kg/ha) of atrazine and ametryne. However, this increase was greater with atrazine than with ametryne. Surface tension was reduced by an increased rate of application of atrazine. This could occur if viscosity had a pronounced effect on contact angle. Viscosity appeared to have greater effect with atrazine than ametryne. Addition

of surfactants to both atrazine and ametryne reduced the contact angle considerably. However, various rates of surfactants ranging from 0.5 to 2.0% did not have any effect on contact angle except with Triton B-1956 where lower contact angle values were recorded at 2% than 0.5 and 1.0%. In presence of surfactants, there was no difference between the contact angles of atrazine and ametryne solutions at any rate of application. Minimum values of contact angle were recorded when Surfactant-WK was used and maximum with Tween-20. Effect of Sun Oil 11E on contact angle was comparable to surfactants, especially Ortho X-77 and Triton X-114. The effect of herbicide-surfactant combinations on surface tension and contact angle cannot be discussed more precisely since technical material of atrazine and ametryne was not used for such determinations. On the basis of surface tension reduction ability and contact angle reduction ability, Surfactant-WK, Span-20 and Tween-20 were classified as strong, medium and weak, respectively. Therefore, the effect of these three surfactants was studied further in greenhouse and field experiments.

Growth Chamber Experiments

Experiment 1

Atrazine at 1.12 kg/ha and ametryne at 0.56 were not phytotoxic to sugarcane or grasses under low temperature and low humidity conditions. As the temperature was increased from low to high, activity of both herbicides increased under low humidity. The highest activity of both herbicides

was recorded under high temperature and high relative humidity conditions. Ametryne was slightly phytotoxic to sugarcane under these conditions. Phytotoxic symptoms were more pronounced in variety CP63-588 than in CL41-223.

Sugarcane treated with atrazine 1.12 kg/ha produced higher fresh and dry weight of shoots and roots than when treated with ametryne at 0.56 kg/ha. The fresh weight of sugarcane roots was not affected by herbicide treatments (Table 19). Variety CL41-223 produced higher shoot weight (fresh and dry) than CP63-588. The weight of roots for both varieties did not differ significantly. No interaction was found between herbicide treatments and varieties. At high temperatures, higher shoot and root weights were produced. Higher shoot weights but not root weights of sugarcane also were produced under high humidity. The interaction between temperature and humidity could not be evaluated because of lack of an adequate number of chambers with similar sets of temperature and relative humidity for replication. Sugarcane plant weights increased with increased relative humidity at low temperatures in all three treatments and in both varieties but decreased with an increase in relative humidity at high temperatures. Therefore, an interaction between temperature and relative humidity appears to exist. However, it appears that effect of relative humidity is more critical at lower temperatures than at higher temperatures.

Table 19. Shoot and Root Weight Responses at High and Low Temperatures and Relative Humidities

Variety	Herbicide Treatment (kg/ha)	Temp. (C)	Relative Humidity (%)	Weight of Shoot (g) Fresh	Weight of Shoot (g) Dry	Weight of Root (g) Fresh	Weight of Root (g) Dry
CP63-588	Atra. 1.12	Low	Low	16.8	3.8	14.3	2.6
		Low	High	35.5	7.7	22.4	4.3
		High	Low	57.5	14.2	24.5	5.3
		High	High	51.9	12.5	14.3	2.9
	Amet. 0.56	Low	Low	15.8	3.2	11.8	2.0
		Low	High	33.3	6.7	22.7	4.4
		High	Low	59.6	12.7	25.7	4.4
		High	High	49.6	12.1	18.9	3.3
	Control	Low	Low	16.2	3.3	13.9	2.0
		Low	High	34.2	6.5	18.8	3.6
		High	Low	63.5	14.2	24.5	4.5
		High	High	54.9	12.6	18.6	3.4
CL 41-223	Atra. 1.12	Low	Low	26.8	5.9	16.0	2.9
		Low	High	37.4	8.6	14.9	4.2
		High	Low	65.6	14.5	24.1	2.9
		High	High	71.4	17.1	23.0	4.5
	Amet. 0.56	Low	Low	16.2	4.8	11.2	2.0
		Low	High	38.6	7.7	14.7	4.1
		High	Low	55.0	12.6	23.0	4.7
		High	High	57.9	14.0	21.0	3.4
	Control	Low	Low	22.3	4.9	11.8	2.4
		Low	High	40.4	8.5	17.1	4.1
		High	Low	60.3	14.0	15.7	3.9
		High	High	61.1	13.8	15.2	2.8

Experiment 2

Phytotoxicity of atrazine and ametryne were recorded qualitatively. Phytotoxic symptoms were visible 4 days after spraying in plants grown at high temperatures but could not be detected until 7 days after spraying in plants grown at low temperatures. Ametryne at 0.56 kg/ha was more phytotoxic to both grasses than atrazine at 1.12 kg/ha. However, atrazine at 1.12 kg/ha suppressed the growth of both grasses. Effect of relative humidity was not detectable at higher temperatures, but herbicides were more phytotoxic at lower temperatures under high relative humidity. The total number of grass plants was counted and recorded before and after the application of treatments and the percent control of grasses was calculated (Table 20). Neither of the herbicides controlled the grasses

Table 20. Annual Grass Control by Herbicides at High and Low Temperatures and Relative Humidities.

Treatment	Grass Control (%)			
	Low Temp. Low Humid.	Low Temp. High Humid.	High Temp. Low Humid.	High Temp. High Humid.
Atra. 1.12 kg/ha	0	5	25	50
Amet. 0.56 kg/ha	0	20	45	150
Control	0	0	0	0

under low temperature and low humidity conditions. Ametryne at 0.56 kg/ha gave higher grass control under low temperature-high relative humidity, and at high temperature

with both low and high relative humidity than atrazine at 1.12 kg/ha. Ametryne gave 100% control of both grasses under high temperature and high relative humidity conditions.

Greenhouse Experiments

Experiment 1

Ametryne + Surfactant-WK treatment was most phytotoxic to both grasses and sugarcane. Phytotoxic symptoms were visible on the grasses in the afternoon of the day of morning treatments. Sugarcane did not show any symptoms until 24 hours after spraying. Both grass species, Alexandergrass and broadleaf panicum, were controlled by atrazine or ametryne + surfactants. Ametryne without surfactant did not control the grasses completely and was more effective than atrazine alone. Ametryne + surfactants were more phytotoxic to both grasses and sugarcane than atrazine + surfactants. Among surfactants, Surfactant-WK caused the greatest increase in phytotoxicity of both herbicides. Span-20, Tween-20 and Span-20 + Tween-20 were equal in effect and more phytotoxic with ametryne than with atrazine.

Atrazine + Surfactant-WK, ametryne, ametryne + Surfactant-WK, ametryne + Span-20, ametryne + Tween-20, and ametryne + Span-20 + Tween-20 reduced the plant height of sugarcane as compared to other treatments. Ametryne + Surfactant-WK killed sugarcane plants within 2 weeks after spraying. The least decrease in plant height between treatment application and harvest was recorded from atrazine

treatments (Table 21). After only 10 days, differences in plant height were significant at the 5% level while at 20 and 30 days after spraying, the differences were significant at the 1% level. This indicated that a lag period was required for the treatments to become phytotoxic. Height increase in atrazine treatments indicated low phytotoxicity to the sugarcane, although grass growth was suppressed and crop-weed competition was reduced.

Minimum fresh and dry weights of crop and grasses were recorded after treatment with ametryne + Surfactant-WK followed by atrazine + Surfactant-WK (Table 22). Maximum and significantly higher weights of sugarcane shoots were obtained under atrazine, atrazine + Tween-20 and atrazine + Span-20 + Tween-20. Ametryne reduced the crop weights significantly as compared to atrazine applied with surfactants. Plants treated with atrazine alone produced higher root weights than other treatments. Atrazine with surfactants did not affect root weights which were significantly higher than with ametryne and surfactant combinations. Highest fresh weight of grasses was recorded from the untreated control followed by atrazine alone. Dry weight of grasses was reduced by all the treatments as compared to control. However, atrazine and atrazine + Span-20 + Tween-20 produced higher grass weight than other treatments.

This experiment indicated that atrazine at 1.12 kg/ha + Surfactant-WK and ametryne at 0.56 kg/ha in combination with all surfactants controlled both grass weeds effectively

Table 21. Sugarcane Plant Height (cm) Response to Herbicide Surfactant Treatments

Treatments	Days after Spraying				Difference
	0	10	20	30	(30-0)
Atra. 1.12 kg/ah	18.2a	24.4a	24.6A	25.6A	7.4
Atra. 1.12 kg/ha + Surf.-WK 1%	20.2a	22.2ab	21.4AB	21.9AB	1.7
Atra. 1.12 kg/ha + Span-20 1%	20.8a	23.1ab	24.9A	26.3A	5.5
Atra. 1.12 kg/ha + Tween-20 1%	19.3a	20.6bc	22.1AB	24.6A	5.4
Atra. 1.12 kg/ha + Span 20 + Tween 20 1%	21.7a	23.2ab	24.0A	25.9A	4.2
Amet. 0.56 kg/ha	19.3a	21.0b	21.1AB	22.0AB	2.7
Amet. 0.56 kg/ha + Surf.-WK 1%	20.1a	20.9b	---	---	---
Amet. 0.56 kg/ha + Span-20 1%	20.8a	22.4ab	22.9AB	23.0AB	2.2
Amet. 0.56 kg/ha + Tween-20 1%	20.2a	21.3ab	21.9AB	21.7AB	1.7
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	16.3a	17.5d	18.3B	18.9B	2.6
Control	19.2a	23.2ab	23.8A	24.7A	5.5

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% level, respectively.

Table 22. Sugarcane Shoot, Root, and Grass Weight Responses to Herbicide-Surfactant Treatments

Treatments	Weight of Sugarcane (g/Plant)				Weight of Grass (g/Pot)		Phytotoxicity Rank
	Shoot		Root				
	Fresh	Dry	Fresh	Dry	Fresh	Dry	
Atra. 1.12 kg/ha	42.2A	8.7A	8.5A	6.3A	8.6B	1.0B	1
Atra. 1.12 kg/ha + Surf.-WK 1%	11.9DE	2.9E	2.4C	1.5C	0.9C	0.2C	4
Atra. 1.12 kg/ha + Span-20 1%	35.3AB	7.3AB	6.0B	4.1B	2.8C	0.4C	4
Atra. 1.12 kg/ha + Tween-20 1%	41.0A	8.1A	7.0AB	5.0B	6.1B	0.7C	2
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	38.1A	7.4AB	7.0AB	4.6B	4.9BC	0.7B	3
Amet. 0.56 kg/ha	27.5BC	6.0BC	3.6C	4.0B	2.3C	0.3C	5
Amet. 0.56 kg/ha + Surf.-WK 1%	4.3E	2.7E	2.0C	1.1C	0.4C	0.1C	10
Amet. 0.56 kg/ha + Span-20 1%	18.5CD	3.9DE	2.7C	1.6C	1.4C	0.3C	8
Amet. 0.56 kg/ha + Tween-20 1%	24.5C	5.2CD	3.3C	2.2C	1.8C	0.3C	6
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	22.6C	4.9CD	2.9C	1.9C	1.6C	0.3C	7
Control	24.2C	6.3BC	6.6B	2.1C	27.3A	4.3A	-

Means in the same column followed by the same letter are not significantly different; capital letters represent significance at 1% level.

but were severely phytotoxic to sugarcane. The next two experiments were conducted with lower rates of atrazine and ametryne and lower concentrations of surfactants to determine a suitable combination of herbicide and surfactant for grass control without suppressing crop growth.

Experiment 2

Atrazine alone at 0.56 kg/ha or at 1.12 kg/ha did not control grasses although the higher rate suppressed grass growth. Atrazine at 1.12 kg/ha + Surfactant-WK at 0.5% was the treatment most phytotoxic to both grasses and sugarcane. The second most effective treatment in controlling grasses was atrazine at 0.56 kg/ha + Surfactant-WK at 0.25%. This combination was less phytotoxic to sugarcane. Both treatments killed grasses within 3 days of application. Atrazine at 1.12 kg/ha with Span-20, Tween-20, and Span-20 + Tween-20 were more effective in controlling the grasses than atrazine at 0.56 kg/ha with the same surfactants. However, grasses were effectively controlled at both rates (0.56 and 1.12 kg/ha) of atrazine with both concentrations (0.25 and 0.5%) of all surfactants. The grasses were killed within 1 week of application although the lethal effect was much faster at the high rates. Crop growth suppression was greater from 1.12 kg/ha atrazine with surfactants than from 0.56 kg/ha atrazine with surfactants.

Twenty days after spraying, sugarcane heights differed at the 5% level of significance and after 30 days they differed at the 1% level of significance (Table 23).

Table 23. Sugarcane Plant Height (cm) Responses to Atrazine-Surfactant Treatments

Treatments	Days after Spraying			Difference
	0	20	30	(30-0)
Atra. 0.56 kg/ha	11.8a	16.3a-c	16.8A-C	5.0
Atra. 0.56 kg/ha + Surf.-WK 0.25%	11.3a	15.3bc	16.0BC	4.7
Atra. 0.56 kg/ha + Span-20 0.25%	12.4a	17.3ab	19.1AB	6.7
Atra. 0.56 kg/ha + Tween-20 0.25%	11.9a	17.0a-c	18.5A-C	6.6
Atra. 0.56 kg/ha + Span-20 + Tween-20 0.25%	11.5a	16.5a-c	19.1AB	7.6
Atra. 1.12 kg/ha	12.3a	18.3a	19.7A	7.4
Atra. 1.12 kg/ha + Surf.-WK 0.5%	11.1a	14.8c	15.7C	4.6
Atra. 1.12 kg/ha + Span-20 0.5%	12.5a	16.1a-c	17.5A-C	5.0
Atra. 1.12 kg/ha + Tween-20 0.5%	12.5a	16.7a-c	18.1A-C	5.6
Atra. 1.12 kg/ha + Span-20 + Tween-20 0.5%	14.2a	16.6a-c	18.2A-C	4.0
Control	12.5a	15.6bc	16.3BC	3.8

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% levels, respectively.

Atrazine at 1.12 and 0.56 kg with both surfactant concentration (0.5 and 0.25%) reduced plant height than other treatments. Greater plant heights were recorded at 0.56 kg/ha atrazine with the 0.25% surfactant level than with 1.12 kg/ha atrazine with the 0.50% surfactant level. The minimum increase in plant height was recorded in the untreated control in which grass weeds were competing with sugarcane.

Fresh and dry weights of grasses for all atrazine + surfactant treatments were zero because grasses were killed by these treatments. Maximum fresh and dry weight of grasses were recorded in the control followed by atrazine at 0.56 and 1.12 kg/ha (Table 24). Atrazine at 0.56 kg/ha + Surfactant-WK and atrazine at 1.12 kg/ha reduced fresh and dry weights of sugarcane. Fresh and dry weights of sugarcane roots were not affected by the various treatments.

Experiments 3

Addition of surfactants consistently increased the activity of ametryne. Ametryne at 0.56 kg/ha + Surfactant-WK was most phytotoxic to grasses and sugarcane. Grass weeds were effectively controlled at both levels of ametryne with both surfactant concentrations. Ametryne alone at 0.56 kg/ha was more effective than ametryne at 0.28 kg/ha. Sugarcane growth was suppressed more at higher rates of ametryne with higher concentration of surfactants.

The treatments affected the height of sugarcane plants significantly (Table 25). The average increase in plant

Table 24. Sugarcane Shoot, Root, and Grass Weight Responses to Atrazine-Surfactant Treatments

Treatments	Wt.of Sugarcane Shoot(g)		Wt.of Sugarcane Root(g)		Wt.of Grass(g)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry
Atra. 0.56 kg/ha	23.1BC	10.3a-c	11.0a	5.3a	15.7	5.5
Atra. 0.56 kg/ha + Surf.-WK 0.25%	26.7A-C	10.6a-c	13.9a	5.0a	0	0
Atra. 0.56 kg/ha + Span-20 0.25%	33.1A	11.3ab	16.0a	6.2a	0	0
Atra. 0.56 kg/ha + Tween-20 0.25%	30.1A	10.6a-c	11.9a	4.8a	0	0
Atra. 0.56 kg/ha + Span-20 + Tween-20 0.25%	28.6A-C	10.3a-c	13.3a	4.6a	0	0
Atra. 1.12 kg/ha	32.6AB	11.7a	15.7a	5.3a	13.7	4.8
Atra. 1.12 kg/ha + Surf.-WK 0.5%	25.5A-C	9.8c	10.4a	4.1a	0	0
Atra. 1.12 kg/ha + Span-20 0.5%	30.3A-C	10.5a-c	14.9a	4.6a	0	0
Atra. 1.12 kg/ha + Tween-20 0.5%	31.0A-C	11.2a-c	13.5a	4.8a	0	0
Atra. 1.12 kg/ha + Span-20 + Tween-20 0.5%	33.7A	11.7a	15.9a	5.0a	0	0
Control	22.7C	10.2bc	14.3a	5.0a	19.7	6.6

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% levels, respectively.

height was greater at 0.28 kg/ha than at 0.56 kg/ha of ametryne. The maximum increase (13.6 cm) in height after 30 days was recorded for ametryne 0.28 kg/ha + Surfactant-WK at 0.25% while the minimum increase (7.8 cm) was recorded from ametryne at 0.56 kg/ha + Surfactant-WK at 0.50%. The mixture of Span-20 + Tween-20 with ametryne reduced plant height significantly as compared to Span-20 and Tween-20 applied individually with ametryne.

Higher weights of sugarcane shoots were recorded at 0.28 kg/ha of ametryne than at 0.56 kg/ha of ametryne. Ametryne at 0.56 kg/ha + Surfactant-WK produced minimum fresh and dry weights of sugarcane (Table 25). The various treatments did not affect fresh and dry root weights. Untreated control plants were shortest and produced minimum fresh and dry weight because of grass competition.

Surfactant concentrations were 1% in the first experiment and were reduced to 0.5 and 0.25% in the second and third experiments. Injury to sugarcane was noticed even at 0.25% concentration of Surfactant-WK. It was suspected that the surfactant itself might have some phytotoxic effect on vegetation. To determine this, an experiment was designed to test the phytotoxicity of various surfactant concentrations on grasses and sugarcane. Two rates of atrazine and ametryne and a control were included for comparison.

Experiment 4

Atrazine alone was not phytotoxic at any rate to either sugarcane or grasses. Ametryne at 0.56 kg/ha effectively

Table 25. Plant Height, Shoot and Root Weight Responses of Sugarcane to Ametryne-Surfactant Treatments

Treatments	Plant Height (cm) Days after Spraying			Weight of Shoot(g)		Weight of Root(g)	
	0	30	Diff. (30-0)	Fresh	Dry	Fresh	Dry
Amet. 0.28 kg/ha	10.4a	32.2AB	12.8	38.8A	13.1a	9.5a	6.6a
Amet. 0.28 kg/ha + Surf.-WK 0.25%	10.7a	24.3A	13.6	36.8AB	12.3ab	9.2a	5.8a
Amet. 0.28 kg/ha + Span-20 0.25%	11.8a	22.8A-C	11.0	36.9AB	12.7a	12.1a	6.6a
Amet. 0.28 kg/ha + Tween-20 0.25%	11.2a	22.6A-C	11.4	38.8A	13.1a	12.3a	7.0a
Amet. 0.28 kg/ha + Span-20 + Tween-20 0.25%	10.3a	19.8B-D	9.5	33.4A-C	12.1ab	10.4a	6.6a
Amet. 0.56 kg/ha	12.2a	22.1A-C	9.9	37.9A	12.9a	8.6a	6.4a
Amet. 0.56 kg/ha + Surf.-WK 0.5%	11.2a	19.0CD	7.8	26.3C	10.6b	6.7a	4.8a
Amet. 0.56 kg/ha + Span-20 0.5%	12.5a	22.9A-C	10.4	37.5A	12.5ab	9.9a	6.0a
Amet. 0.56 kg/ha + Tween-20 0.5%	11.1a	20.5A-D	9.4	33.4A-C	11.9ab	11.0a	8.0a
Amet. 0.56 kg/ha + Span-20 + Tween-20 0.5%	12.6a	19.8B-D	7.2	36.9AB	13.0a	12.1a	6.2a
Control	12.0a	17.7D	5.7	28.3BC	12.4ab	10.4a	6.5a

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% level, respectively.

controlled grasses but was more phytotoxic to sugarcane than ametryne at 0.28 kg/ha. Surfactant-WK was most phytotoxic to both grasses and sugarcane and phytotoxicity increased with increased concentration. Span-20, Tween-20 and Span-20 + Tween-20 did not cause direct phytotoxic symptoms to sugarcane but caused wilting and twisting in the grasses. These symptoms increased as the surfactant concentration was increased from 0.5% to 2.0%. These symptoms were less noticeable with Tween-20 than Span-20 and Span-20 + Tween-20.

Ametryne at 0.28 kg/ha did not kill sugarcane terminal buds but growth was reduced for 30 days. Ametryne at 0.56 kg/ha killed terminal buds. All three concentrations of Surfactant-WK killed terminal buds within one week of spraying and new lateral shoots emerged. Plant height was not affected by Tween-20, Span-20 and Tween-20 + Span-20 although Tween-20 + Span-20 at 2.0% reduced plant height at 30 days after spraying (Table 26).

Surfactant-WK at 2.0% reduced fresh and dry weight of sugarcane than the other treatments. Surfactant-WK at 1.0% and ametryne at 0.56 kg/ha treatments had comparable fresh weights, and lower than the other treatments. Higher fresh weights were recorded for Tween-20 treated plants. Ametryne at 0.56 kg/ha and Surfactant-WK at all three concentrations reduced the dry weight of sugarcane shoots significantly than the other treatments. Fresh and dry weights of sugarcane roots were affected similarly (Table 26).

Table 26. Sugarcane Plant Height, Shoot and Root Weight Responses to Atrazine, Ametryne and Surfactant Treatments

Treatments	Plant Height (cm) Days after Spraying			Weight of Shoot (g)		Weight of Root (g)	
	0	30	Diff. (30-0)	Fresh	Dry	Fresh	Dry
Atra. 0.56 kg/ha	24.8b-c	32.9A-C	8.1	65.5C-E	20.8AB	16.4B-E	8.1A-C
Atra. 1.12 kg/ha	21.8d-f	30.8B-E	9.0	57.3D-F	17.6BC	11.9E-H	6.4DE
Amet. 0.28 kg/ha	24.3c-e	27.2EF	2.9	46.3FG	14.9CD	9.3F-I	4.8F
Amet. 0.56 kg/ha	20.1f	20.2G	0.1	27.1HI	10.2E	4.8I	3.0G
Surf.-WK 0.5%	23.8c-e	---	---	36.1GH	11.6E	8.3G-I	4.3F
Surf.-WK 1.0%	25.3b-d	---	---	25.7HI	10.3E	8.5G-I	4.1FG
Surf.-WK 2.0%	24.9b-e	---	---	14.9I	10.1E	5.7HI	3.7FG
Span-20 0.5%	28.1ab	33.8A-C	5.7	71.9A-C	21.1AB	22.4AB	8.1A
Span-20 1.0%	28.4ab	33.8A-C	5.4	74.5A-C	21.0AB	20.0A-C	7.5A-D
Span-20 2.0%	29.5a	34.3AB	4.8	81.3AB	23.3A	20.2A-C	7.9A-C
Tween-20 0.5%	28.2ab	26.0A	7.8	84.8AB	23.6A	19.2A-D	7.3A-D
Tween-20 1.0%	26.0a-c	34.3AB	8.3	78.6A-C	20.3AB	13.0D-G	6.7B-D
Tween-20 2.0%	25.7bc	33.0A-C	7.3	84.9AB	20.7AB	14.3C-G	6.7CD
Span-20 + Tween-20 0.5%	25.3b-d	34.8AB	9.5	86.7A	23.6A	17.6B-E	7.5A-D
Span-20 + Tween-20 1.0%	23.5c-f	32.2A-D	8.7	77.6A-C	21.0AB	1 5.9B-F	7.2A-D
Span-20 + Tween-20 2.0%	25.7bc	27.8DE	2.1	70.4B-D	18.7B	24.9A	8.1AB
Control	21.3ef	29.3C-E	8.0	54.5EF	18.0BC	17.7B-E	7.2A-D

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% level, respectively.

Field Experiments

Experiment 1

Ametryne at 0.56 kg/ha + surfactant treatments generally were more phytotoxic to both crop and annual grasses and broadleaf weeds than atrazine at 1.12 kg/ha + surfactants. However, atrazine at 1.12 kg/ha + Surfactant-WK at 1% was less phytotoxic than ametryne 0.56 kg/ha + Surfactant-WK 1% but more phytotoxic than ametryne at 0.56 kg/ha + Span-20, Tween-20 or Span-20 + Tween-20 at 1% concentration. Atrazine at 1.12 kg/ha + Surfactant-WK at 1% and ametryne at 0.56 kg + Surfactant-WK effectively controlled weeds except purple nutsedge which was not controlled by any of the treatments. Other treatments suppressed growth of grass and broadleaf weeds and did not provide effective control. Crop injury was not noticed in these treatments. Phytotoxicity to two varieties of sugarcane due to treatments was similar except that scorching of leaves was more noticeable in CP63-588 than CL41-223. Both varieties recovered as crop growth advanced.

The number of sugarcane stalks per plot was counted at 1 month intervals for the first 6 months of the growing season (Table 27). The herbicide-surfactant combinations did not affect the sugarcane plant populations significantly. However, plots treated with atrazine at 1.12 kg/ha had higher numbers of stalks per plot than plots treated with ametryne at 0.56 kg/ha at 2, 3, 4, 5, and 6 months after herbicide application. Variety CP63-588 had a higher number

Table 27. Number of Stalks/Plot Responses to Herbicide-Surfactant Treatments at Various Stages in Two Varieties of Sugarcane

Treatments	Months after Planting								
	1			2			3		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	56	50	53a	122	99	111a	129	113	121a
Atra. 1.12 kg/ha + Span-20 1%	59	52	56a	133	96	115a	141	107	124a
Atra. 1.12 kg/ha + Tween-20 1%	57	55	56a	121	99	110a	133	117	125a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	54	59	57a	109	110	110a	129	123	121a
Amet. 0.56 kg/ha + Surf.-WK 1%	58	44	51a	122	82	102a	120	96	108a
Amet. 0.56 kg/ha + Span-20 1%	56	50	53a	119	89	104a	121	97	109a
Amet. 0.56 kg/ha + Tween-20 1%	63	54	59a	118	97	108a	117	104	111a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	53	48	51a	102	95	99a	114	115	115a
Control	59	51	55a	116	96	106a	132	108	120a
Varietal Mean	57A	51B		118A	96B		125A	109B	

Means in the same column followed by the same letter are not significantly different; varietal means within specific months followed by the same letter are not significantly different. Capital and small letters represent significance at 1% and 5% level, respectively.

Table 27. --Continued.

Treatments	Months after Planting								
	4			5			6		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	142	136	139a	131	127	129a	121	126	124a
Atra. 1.12 kg/ha + Span-20 1%	157	126	142a	127	131	129a	131	130	131a
Atra. 1.12 kg/ha + Tween-20 1%	150	133	142a	124	126	125a	123	135	129a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	138	134	136a	117	133	125a	114	125	120a
Amet. 0.56 kg/ha + Surf.-WK 1%	124	111	118a	103	115	109a	99	130	115a
Amet. 0.56 kg/ha + Span-20 1%	123	116	120a	107	116	112a	102	127	115a
Amet. 0.56 kg/ha + Tween-20 1%	120	120	120a	109	128	119a	105	123	114a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	122	121	122a	100	108	104a	96	118	107a
Control	147	114	131a	126	116	121a	124	112	118a
Varietal Mean	136A	124B		116a	122a		113B	125A	

Means in the same column followed by the same letter are not significantly different; varietal means within specific months followed by the same letter are not significantly different. Capital and small letters represent significance at 1% and 5% level, respectively.

of stalks per plot than CP63-588. The numbers of stalks per plot increased through the first 4 months after planting for both varieties. Between 4 and 6 months, no increase occurred in number of stalks per plot in CL41-223 while the numbers of stalks per plot decreased in CP63-588. Therefore, numbers of stalks per plot in CL41-223 was greater at 6 months than in CP63-588. Reduction in numbers of stalks resulted from vigorous plants suppressing the growth of smaller and weaker plants and weed competition. There was no treatment X variety interaction at any date.

The height of sugarcane stalks was measured at 3, 4, 5, 6.5, 8, and 9.5 months after treatment application (Table 28). Plots treated with atrazine at 1.12 kg/ha produced taller stalks than treatments with ametryne at 0.56 kg/ha at all except the 3 month measurement. Ametryne 0.56 kg/ha reduced the stalk height compared with the untreated control. Overall, sugarcane plots treated with ametryne at 0.56 kg/ha with surfactants had lower heights than plots treated with atrazine at 1.12 kg/ha with surfactants at all dates for both varieties. Stalk height was not influenced by the various surfactants. Variety CP63-588 had taller stalks than CL41-223 as could be expected from the normal growth pattern of these varieties. There was a constant increase in stalk height for both varieties until 9.5 months, however, the highest (63 cm) and lowest (8 cm) increase was recorded between 5 and 6.5, and 8 and 9.5 months,

Table 28. Stalk Height (cm - TVD) Responses to Herbicide-Surfactant Treatments at Various Stages in Two Varieties of Sugarcane

Treatments	Months after Planting								
	3			4			5		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	26	22	24a	75	64	69A-C	133	114	124A
Atra. 1.12 kg/ha + Span-20 1%	28	21	25a	77	62	70AB	141	114	128A
Atra. 1.12 kg/ha + Tween-20 1%	24	21	23a	69	64	67A-D	128	112	120AB
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	24	22	23a	72	62	67A-D	136	119	128A
Amet. 0.56 kg/ha + Surf.-WK 1%	26	22	24a	56	50	53E	115	94	105C
Amet. 0.56 kg/ha + Span-20 1%	27	22	25a	64	52	58B-E	121	100	111BC
Amet. 0.56 kg/ha + Tween-20 1%	25	22	24a	60	62	56C-E	116	98	107C
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	26	22	24a	57	51	54DE	112	98	105C
Control	26	22	24a	80	69	75A	135	120	128A
Varietal Mean	26A	22B		68A	58B		126A	108B	

Means in the same column followed by the same letter are not significantly different; varietal means within specific months followed by the same letter are not significantly different. Capital and small letters represent significance at 1% and 5% level, respectively.

Table 28. --Continued.

Treatments	Months after Planting								
	6.5			8			9.5		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	205	181	193A	235	228	232AB	249	236	243A
Atra. 1.12 kg/ha + Span-20 1%	212	178	195A	249	224	237A	256	236	246A
Atra. 1.12 kg/ha + Tween-20 1%	201	179	190AB	239	212	226A-C	246	225	236AB
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	202	188	195A	242	224	233AB	244	236	240A
Amet. 0.56 kg/ha + Surf.-WK 1%	188	153	171C	220	203	212C	233	202	218C
Amet. 0.56 kg/ha + Span-20 1%	186	162	174C	224	213	219BC	234	205	220C
Amet. 0.56 kg/ha + Tween-20 1%	186	161	174C	223	200	212C	233	211	222C
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	190	158	174C	221	210	216C	236	208	222C
Control	206	187	197A	243	230	237A	253	235	244A
Varietal Mean	197A	172B		233A	216B		243A	222B	

Means in the same column followed by the same letter are not significantly different; varietal means within specific months followed by the same letter are not significantly different. Capital and small letters represent significance at 1% and 5% level, respectively.

respectively, for both varieties. There was no treatment X variety interaction at any date.

Brix, polariscope reading, sucrose, and purity of sugarcane juice were determined as measures of juice quality. The herbicide-surfactant combinations did not affect the juice quality (Table 29). Variety CP63-588 had higher brix, polariscope reading, sucrose, and purity values than CL441-223. There was no treatment X variety interaction.

Overall, 10-stalk weights from atrazine at 1.12 kg/ha were greater than from ametryne at 0.56 kg/ha (Table 30). Surfactants did not affect 10-stalk weight when applied with atrazine but they had varying effect when applied with ametryne. A combination of ametryne 0.56 kg/ha + Surfactant-WK at 1% significantly reduced the 10-stalk weight as compared with other treatments. Variety CP63-588 produced higher 10-stalk weights than did CL41-223. There was no treatment X variety interaction.

Plants treated with atrazine at 1.12 kg/ha produced higher 10-stalk juice weight as compared to ametryne at 0.56 kg/ha (Table 30). The trend was the same as for 10-stalk cane weight. Variety CP63-588 produced higher 10-stalk juice weights than CL41-223. There was no treatment X variety interaction.

Plots treated with atrazine at 1.12 kg/ha with surfactants yielded 70.5 tons/ha of sugarcane, significantly greater than the 60.0 tons/ha recorded from ametryne 0.56 kg/ha with surfactants. Among the surfactants, Surfactant-WK

Table 29. Juice Quality Responses to Herbicide-Surfactant Treatments in Two Varieties of Sugarcane

Treatments	Brix (°)			Pol. Reading		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	20.9	19.4	20.2a	18.3	74.4	77.9a
Atra. 1.12 kg/ha + Span-20 1%	21.0	19.0	20.0a	81.5	73.1	77.3a
Atra. 1.12 kg/ha + Tween-20 1%	20.8	19.3	20.3a	80.2	72.9	76.6a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	21.0	19.4	20.2a	81.6	74.1	77.9a
Amet. 0.56 kg/ha + Surf.-WK 1%	20.2	19.0	19.6a	78.1	72.0	75.1a
Amet. 0.56 kg/ha + Span-20 1%	20.8	19.4	20.1a	80.6	73.8	77.2a
Amet. 0.56 kg/ha + Tween-20 1%	20.5	19.0	19.8a	78.9	72.7	75.8a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	20.6	19.4	20.0a	79.7	74.3	77.0a
Control	20.9	19.4	20.2a	81.0	74.6	77.8a
Varietal Mean	20.7a	19.3B		80.3A	73.5B	

Means in the same column followed by the same letter are not significantly different; varietal means followed by the same letter in each data set do not differ significantly. Capital and small letters represent significance at 1% and 5% level, respectively.

Table 29. --Continued.

Treatments	Sucrose Content in Juice (%)			Purity of Juice (%)		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	19.5	17.9	18.7a	93.0	92.3	92.4a
Atra. 1.12 kg/ha + Span-20 1%	19.5	17.7	18.6a	92.9	91.9	92.4a
Atra. 1.12 kg/ha + Tween-20 1%	19.2	17.6	18.4a	92.5	91.5	92.0a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	19.5	17.9	18.7a	92.8	92.1	92.5a
Amet. 0.56 kg/ha + Surf.-WK 1%	18.8	17.4	18.1a	92.8	91.5	92.2a
Amet. 0.56 kg/ha + Span-20 1%	19.3	17.8	18.6a	93.0	91.7	92.4a
Amet. 0.56 kg/ha + Tween-20 1%	18.9	17.6	18.3a	92.5	92.2	92.4a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	19.1	17.9	18.5a	92.6	92.5	92.6a
Control	19.4	18.0	18.7a	92.7	92.6	92.7a
Varietal Mean	19.2A	17.7B		92.8A	92.0B	

Means in the same column followed by the same letter are not significantly different; varietal means followed by the same letter in each data set do not differ significantly. Capital and small letters represent significance at 1% and 5% level, respectively.

Table 30. Yield and Yield Contributing Character Responses to Herbicide-Surfactant Treatments in Two Varieties of Sugarcane

Treatments	10 Stalk Wt. (kg)			10 Stalk Juice Wt. (kg)			Juice Content (%)		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	14.3	12.8	13.6A-C	7.9	6.9	7.4ab	55.2	53.9	54.6a
Atra. 1.12 kg/ha + Span-20 1%	15.6	13.1	14.4AB	8.5	7.0	7.8ab	54.5	53.4	54.0a
Atra. 1.12 kg/ha + Tween-20 1%	15.0	11.9	13.5AC	8.2	6.4	7.3ab	54.7	58.8	54.3a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	13.8	13.6	13.7A-C	7.6	7.3	7.5ab	55.1	53.7	54.4a
Amet. 0.56 kg/ha + Surf.-WK 1%	12.0	11.1	11.6C	6.7	5.7	6.2c	55.8	51.4	53.6a
Amet. 0.56 kg/ha + Span-20 1%	13.8	11.3	12.6A-C	7.6	6.2	6.9a-c	55.1	54.9	55.0a
Amet. 0.56 kg/ha + Tween-20 1%	14.2	10.2	12.2BC	7.9	5.5	6.7bc	55.6	53.9	54.8a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	14.5	11.9	13.2A-C	7.7	6.5	7.1a-c	53.1	54.6	53.9a
Control	14.7	14.4	14.6A	8.0	7.8	7.9a	54.4	54.2	54.3a
Varietal Mean	14.2A	12.3B		7.8A	6.6B		54.8a	53.8a	

Means in the same column followed by the same letter are not significantly different; varietal means followed by the same letter in each data set do not differ significantly. Capital and small letters represent significance at 1% and 5% level, respectively.

Table 30. --Continued.

Treatments	Yield of Sugarcane (tons/ha)			kg Sugar/Ton Cane		
	CP63 588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	73.8	53.6	63.7ab	142.9	128.4	135.7a
Atra. 1.12 kg/ha + Span-20 1%	79.8	64.8	72.3a	143.0	126.3	134.7a
Atra. 1.12 kg/ha + Tween-20 1%	78.9	65.9	72.4a	140.7	125.6	133.2a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	69.5	77.3	73.4a	143.2	127.8	135.5a
Amet. 0.56 kg/ha + Surf.-WK 1%	54.4	46.6	50.6b	137.6	124.1	130.9a
Amet. 0.56 kg/ha + Span-20 1%	65.9	62.1	64.0ab	141.7	127.2	134.5a
Amet. 0.56 kg/ha + Tween-20 1%	66.8	59.4	63.1ab	138.7	125.8	132.3a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	61.2	63.0	62.1ab	140.0	128.5	134.3a
Control	79.8	62.8	71.3a	142.3	129.1	135.7a
Varietal Mean		70.0A	61.7B		141.1A	127.0B

Means in the same column followed by the same letter are not significantly different; varietal means followed by the same letter in each data set do not differ significantly. Capital and small letters represent significance at 1% and 5% level, respectively.

reduced sugarcane yields with both herbicides as compared to Span-20, Tween-20, and Span-20 + Tween-20. No differences in sugarcane yield were associated with Span-20, Tween-20, and Span-20 + Tween-20. The reduction in yield in ametryne-treated plots as compared to atrazine-treated plots was apparently due to reduction in plant stand and sugarcane stalk height. Yields obtained from untreated control plots were similar to atrazine at 1.12 kg/ha with 1% concentration of Span-20, Tween-20 and Span-20 + Tween-20 but higher than atrazine at 1.12 kg/ha + Surfactant-WK and ametryne at 0.56 kg/ha with all the surfactants. Variety CP63-588 yielded significantly higher sugarcane yield than CL41-223. There was no treatment X variety interaction (Table 30).

Atrazine or ametryne and surfactant combination treatments did not affect the percentage of juice in sugarcane and the amount of sugar per ton of sugarcane. However, variety CP63-588 had higher juice percentage (54.8%) and sugar per ton of sugarcane (141.1 kg) than variety CL41-223, (53.8%) juice and (127.0 kg) sugar per ton of sugarcane (Table 30).

The treatments applied to the plant crop of sugarcane were repeated the following year in the first ratoon crop. Surfactant-WK at 1% concentration applied with 1.12 kg/ha atrazine or 0.56 kg/ha ametryne effectively controlled both grass and broadleaf weeds except purple nutsedge, but were phytotoxic to the crop. The phytotoxicity was more severe with ametryne than with atrazine. Phytotoxicity in the

ratoon crop was less than that in the plant crop. Similar observations have been reported by Peng (1972). Span-20, Tween-20, or Span-20 + Tween-20 applied at 1% concentration either with atrazine or ametryne did not control the weeds effectively, but did suppress grass growth. The suppression of growth was greater with ametryne than atrazine. Phytotoxicity to the crop was not noticed. This crop of ratoon sugarcane was harvested immature when it was 4 months old. The herbicide-surfactant combination treatments did not affect the number of stalks per plot, height of stalks, and fresh and dry weights of the crop. Variety CP63-588 produced taller stalks and greater fresh and dry weights than variety CL41-223, although the latter had a higher number of stalks per plot. Fresh and dry weights of the crop appeared to be affected more by the stalk height than the number of stalks per plot. Higher numbers of shorter stalks did not offset the weight of fewer but taller stalks of CP63-588 (Table 31). There was no treatment X variety interaction.

Experiment 2

Ametryne treatments generally were more effective than atrazine in controlling grass weeds. Within ametryne treatments, the higher rate (0.56 kg/ha) applied with the higher concentration (0.50%) of surfactants was more effective. However, none of the treatments gave 100% control of grass weeds. Among atrazine treatments also, the higher rate (1.12 kg/ha) with the higher surfactant concentration (0.50%)

Table 31. Sugarcane Plant Number, Height, and Weight Responses to Herbicide-Surfactant Treatments in First Ratoon of Two Varieties

Treatments	No. of Stalks/Plot			Height of Stalks (cm)		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	199	239	219a	113	99	106a
Atra. 1.12 kg/ha + Span-20 1%	200	227	213a	118	104	111a
Atra. 1.12 kg/ha + Tween-20 1%	229	227	228a	119	104	112a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	195	231	213a	115	104	110a
Amet. 0.56 kg/ha + Surf.-WK 1%	233	232	233a	111	94	103a
Amet. 0.56 kg/ha + Span-20 1%	187	223	205a	116	98	107a
Amet. 0.56 kg/ha + Tween-20 1%	206	224	215a	113	101	107a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	210	234	222a	110	98	104a
Control	196	199	198a	119	99	109a
Varietal Mean	206B	226B		115A	100B	

Means in the same column followed by the same letter are not significantly different; varietal means followed by the same letter in each data set do not differ significantly. Capital and small letters represent significance at 1% and 5% level, respectively.

Table 31. --Continued.

Treatments	Fresh Weight of Crop (tons/ha)			Dry Weight of Crop (tons/ha)		
	CP63-588	CL41-223	Mean	CP63-588	CL41-223	Mean
Atra. 1.12 kg/ha + Surf.-WK 1%	67.7	65.5	66.6a	17.0	14.0	15.5a
Atra. 1.12 kg/ha + Span-20 1%	76.9	65.7	71.3a	18.7	13.9	16.3a
Atra. 1.12 kg/ha + Tween-20 1%	70.2	63.2	66.7a	16.0	13.7	14.9a
Atra. 1.12 kg/ha + Span-20 + Tween-20 1%	63.2	70.2	66.7a	16.1	14.8	15.5a
Amet. 0.56 kg/ha + Surf.-WK 1%	68.6	55.2	61.9a	16.7	12.5	14.6a
Amet. 0.56 kg/ha + Span-20 1%	71.7	60.8	66.3a	15.4	13.7	14.6a
Amet. 0.56 kg/ha + Tween-20 1%	69.1	59.4	64.3a	17.3	12.2	14.8a
Amet. 0.56 kg/ha + Span-20 + Tween-20 1%	65.0	57.8	61.4a	14.8	11.2	13.0a
Control	76.9	60.1	68.5a	17.4	13.5	15.5a
Varietal Mean	70.0A	62.0B		16.6A	13.3B	

Means in the same column followed by the same letter are not significantly different; varietal means followed by the same letter in each data set do not differ significantly. Capital and small letters represent significance at 1% and 5% level, respectively.

gave better control of weeds. Ametryne at 0.56 kg/ha applied with 0.50% surfactant concentration severely injured the crop while ametryne at 0.28 kg/ha with 0.25% surfactant concentration suppressed crop growth with less noticeable phytotoxic symptoms. Atrazine either at 0.56 or 1.12 kg/ha with either concentration of surfactant did not injure the crop except when Surfactant-WK at 0.50% was applied with 1.12 kg/ha of atrazine. However, this phytotoxicity was less than with any combination of ametryne and surfactants.

Observations on numbers of stalks per plot were recorded on February 1, April 1, and June 1 while the treatments were applied on March 15. Differences in plant populations did not exist initially (February 1) or until 15 days after treatment application (April 1). However, the numbers of stalks per plot were reduced by ametryne at 0.56 kg/ha with a 0.50% surfactant concentration as compared to other treatments at 2.5 month (June 1) after application (Table 32). This reduction in plant population by higher rates of ametryne with higher concentration of surfactants was in agreement with the visible phytotoxicity to the crop. There was steady increase in number of stalks per plot in all treatments from February 1 to June 1 as new tillers emerged.

Sugarcane stalk height was recorded on May 1 and June 1. Plots treated with ametryne and surfactant combination treatments produced shorter stalks than plots treated with atrazine + surfactants. Ametryne at 0.56 kg/ha + surfactants

Table 32. Sugarcane Plant Number, Height (cm), and Weight (tons/ha) Responses to Herbicide-Surfactant Treatments

Treatments	No. of Stalks/Plot			Height of Stalks (cm)		Yield of Sugarcane (tons/ha)	
	Feb.1	April 1	June 1	May 1	June 15	Fresh wt.	Dry wt.
Atra. 0.56 kg/ha	58a	93a	174a-d	92AB	133A	89.0A-C	13.0AB
Atra. 0.56 kg/ha + Surf.-WK 0.25%	56a	91a	176a-d	90A-C	132A	95.0AB	14.7A
Atra. 0.56 kg/ha + Span-20 0.25%	46a	95a	174a-d	80A-D	126A-C	84.7A-F	12.4A-C
Atra. 0.56 kg/ha + Tween-20 0.25%	39a	93a	174a-d	92AB	129AB	90.4A-C	11.9A-D
Atra. 0.56 kg/ha + Span-20 + Tween-20 0.25%	49a	93a	194a	94A	133A	97.1A	14.2A
Atra. 1.12 kg/ha	52a	101a	197a	93AB	129AB	94.2AB	13.1AB
Atra. 1.12 kg/ha + Surf.-WK 0.5%	42a	91a	187a-c	90A-C	131A	88.3A-D	12.5A-C
Atra. 1.12 kg/ha + Span-20 0.5%	55a	93a	176a-d	89A-C	128AB	90.4A-C	14.2A
Atra. 1.12 kg/ha + Tween-20 0.5%	49a	85a	176a-d	94A	132A	87.9A-E	12.5A-C
Atra. 1.12 kg/ha + Span-20 + Tween-20 0.5%	53a	90a	172a-d	92AB	129AB	83.6A-F	13.1AB

Table 32. --Continued.

Treatments	No. of Stalks/Plot			Height of Stalks (cm)		Yield of Sugarcane (tons/ha)	
	Feb. 1	April 1	June 1	May 1	June 15	Fresh wt.	Dry wt.
Amet. 0.28 kg/ha	55a	87a	170a-d	82C-E	122A-E	77.1A-G	9.8B-E
Amet. 0.28 kg/ha + Surf.-WK 0.25%	51a	94a	168a-d	79D-G	115D-F	72.6B-H	10.1B-E
Amet. 0.28 kg/ha + Span-20 0.25%	49a	88a	148b-d	79D-G	114D-F	64.1F-H	8.9DE
Amet. 0.28 kg/ha + Tween-20 0.25%	54a	77a	148b-d	79D-G	116C-F	67.9C-H	9.3C-E
Amet. 0.28 kg/ha + Span-20 + Tween-20 0.25%	60a	100a	190ab	86A-D	125A-D	76.2A-G	10.1B-E
Amet. 0.56 kg/ha	48a	92a	149b-d	84B-E	118B-F	65.2D-H	8.7DE
Amet. 0.56 kg/ha + Surf.-WK 0.5%	44a	91a	147cd	71FG	108F	55.2GH	7.5E
Amet. 0.56 kg/ha + Span-20 0.5%	49a	83a	140d	70G	111EF	57.4GH	7.4E
Amet. 0.56 kg/ha + Tween-20 0.5%	46a	92a	143cd	75E-G	115D-F	64.6E-H	8.7DE
Amet. 0.56 kg/ha + Span-20 + Tween-20 0.5%	59a	95a	135d	72FG	109F	50.9H	6.7E
Control	42a	88a	169a-d	92AB	127AB	86.8A-F	12.8AB

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% level, respectively.

at 0.50% produced shorter stalks than ametryne 0.28 kg/ha + surfactant at 0.25%. The combinations of atrazine rates and surfactant concentrations did not affect the stalk height at either date (Table 32).

The immature crop of sugarcane was harvested on June 15, after 6 months of growth and fresh and dry weights were recorded (Table 32). Atrazine + surfactant treatments produced higher fresh and dry weights than ametryne + surfactant treatments. Ametryne at 0.28 kg/ha with 0.25% surfactant produced higher fresh and dry weights than ametryne at 0.56 kg/ha with 0.50% surfactant while atrazine at 0.56 or 1.12 kg/ha with surfactant concentrations of 0.25 or 0.50% did not affect fresh or dry weights. Surfactant-WK with atrazine had no effect on fresh or dry weights but with ametryne, the higher concentration (0.5%) reduced fresh and dry weights as compared to the lower concentration (0.25%). Span-20, Tween-20, and Span-20 + Tween-20 did not have any effect on fresh and dry weight; however, these surfactants reduced fresh or dry weights when applied with ametryne more than when applied with atrazine.

Experiment 3

Ametryne at 0.56 kg/ha with Surfactant-WK at 1% was the most phytotoxic treatment to both weeds and crop. Greater phytotoxicity to weeds and crop was recorded in ametryne + surfactants treatments than atrazine + surfactant treatments (Table 33). Phytotoxicity of Triton-1956 and Tween-20 appeared equal.

Table 33. Stalk Height (cm) and Phytotoxicity Responses of Sugarcane and Weeds to Herbicide-Surfactant Treatments

Treatments	Height of Stalk (cm)		Phytotoxicity Rating	
	Months after Spraying			
	1	2	Crop	Weeds
Atra. 1.12 kg/ha + Surf.-WK 1%	94A	165ab	1.8	4.7
Atra. 1.12 kg/ha + Triton B-1956 1%	92A	168a	1.5	5.0
Atra. 1.12 kg/ha + Tween-20 1%	94A	167a	1.8	4.5
Amet. 0.56 kg/ha + Surf.-WK 1%	76C	150c	6.7	7.1
Amet. 0.56 kg/ha + Triton B-1956 1%	83B	154bc	5.3	6.3
Amet. 0.56 kg/ha + Tween-20 1%	75C	157b	5.0	6.8
Control	92A	166ab	1.0	1.0

Means in the same column followed by the same letter are not significantly different; capital and small letters represent significance at 1% and 5% level, respectively.

Table 34. Juice Quality Responses to Herbicide-Surfactant Treatments in Ratoon Crop of Sugarcane

Treatments	Brix(°)	Pol. Reading	Sucrose Content in Juice(%)	Purity of Juice (%)
Atra. 1.12 kg/ha + Surf.-WK 1%	18.6a	67.6a	16.4a	88.0a
Atra. 1.12 kg/ha + Triton B-1956 1%	19.0a	69.1a	16.7a	87.5a
Atra. 1.12 kg/ha + Tween-20 1%	19.1a	70.3a	17.0a	87.7a
Amet. 0.56 kg/ha + Surf.-WK 1%	19.2a	69.9a	16.9a	88.2a
Amet. 0.56 kg/ha + Triton B-1956 1%	19.4a	70.7a	17.1a	88.0a
Amet. 0.56 kg/ha + Tween 20 1%	19.0a	69.2a	16.9a	89.1a
Control	20.0a	74.4a	17.9a	89.5a

Means in the same column followed by the same letter are not significantly different.

Atrazine at 1.12 kg/ha with surfactants had taller stalks than ametryne at 0.56 kg/ha with surfactants. Stalk heights did not differ among surfactants applied with atrazine. Surfactant-WK and Tween-20 reduced stalk height at 1 month after spraying as compared to Triton B-1956 when applied with ametryne. At 2 months after spraying, Triton B-1956 and Tween-20 plots had stalks of similar heights, taller than those of Surfactant-WK.

Brix, polariscope reading, sucrose content and purity of juice were not affected by the herbicides or the herbicide-surfactant combinations (Table 34). Weight of 10 stalks, juice weight from 10 stalks, juice content in sugarcane, yield of sugarcane, and kg of sugar per ton of cane were not affected by the herbicides or by the herbicide-surfactant combinations (Table 35).

These experiments demonstrate that the addition of surfactants to atrazine or to ametryne increases the phytotoxic effect. The efficiency of surfactants in reducing surface tension and contact angle agreed with their effect in increasing herbicidal activity of atrazine and ametryne on plants in the greenhouse tests and in the field. The degree of phytotoxicity depended upon the rate of herbicide and concentration of surfactant. Increase in activity of atrazine and ametryne apparently resulted because:

1. Surfactants reduced the surface tension of the spray solutions and droplets became flatter

Table 35. Yield and Yield Contributing Character Responses to Herbicide-Surfactant Treatments in Ratoon Crop of Sugarcane

Treatments	10 Stalk Wt. (kg)	10 Stalk Juice Wt. (kg)	Juice Content (%)	Yield of Sugarcane (tons/ha)	kg of Sugar/ Ton of Cane (kg)
Atra. 1.12 kg/ha + Surf.-WK 1%	15.3a	7.0a	45.8a	115.0a	114.7a
Atra. 1.12 kg/ha + Triton B-1956 1%	14.5a	6.7a	46.2a	115.0a	116.7a
Atra. 1.12 kg/ha + Tween-20 1%	15.7a	7.3a	46.5a	120.4a	119.3a
Amet. 0.56 kg/ha + Surf.-WK 1%	14.5a	7.0a	48.3a	117.8a	118.3a
Amet. 0.56 kg/ha + Triton B-1956 1%	14.3a	6.9a	48.3a	114.2a	119.4a
Amet. 0.56 kg/ha + Tween-20 1%	15.4a	7.3a	47.4a	110.0a	119.2a
Control	14.9a	7.0a	47.0a	111.4a	126.3a

Means in the same column followed by the same letter are not significantly different.

with reduced contact angle and an increase in area of plant surface contacted by the spray.

2. Increased absorption is possible because of the increased area through which absorption could take place.
3. Increased absorption could be caused if surfactants induce changes in cuticular permeability.
4. Surfactants may have reduced the rate of evaporation and allowed spray droplet retention on plant surfaces for a longer absorption period.

SUMMARY AND CONCLUSIONS

This research was done at the Agricultural Research and Education Center, Belle Glade, Florida, and in the Department of Chemical Engineering at the University of Florida, Gainesville.

Surface tension and contact angle were determined for Ortho X-77, Span-20, Sterox NJ, Surfactant-WK, Triton B-1956, Triton X-114, Tween-20, Span-20 + Tween-20 (50:50 v/v), and Sun Oil 11E at the concentrations of 0, 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}, 0.125, 0.25, 0.5, 1.0, 2.0% (v/v) in distilled water, tap water and hard water of 250, 500, 750, and 1,000 ppm hardness as Ca ions. The above surfactants also were used at 0.5, 1.0, and 2% (v/v) concentrations to determine surface tension and contact angle in combination with commercial wettable powder formulations of atrazine and ametryne at application rates of 1.0, 2.0 and 4.0 kg/ha. Increase in surfactant concentration from 0 to 10^{-1}% reduced surface tension and contact angle of the solutions. The degree of reduction varied with surfactants and was dependent on critical micelle concentration. Surfactant concentrations ranging from 0.125 to 2.0% did not further reduce surface tension and contact angle. Water hardness did not affect surface tension and contact angle. Commercial wettable powder ametryne had the lower surface

tension which was not changed by the addition of surfactants except with Surfactant-WK and Tween-20; commercial wettable powder atrazine had the higher surface tension which was reduced by the addition of all surfactants. Contact angle also was higher for atrazine than ametryne. Increased atrazine concentration reduced surface tension in the absence of surfactants but surface tension was not affected by concentration in presence of surfactants. Increased concentration of atrazine and ametryne without surfactant increased contact angle, but this effect was not noted in herbicide surfactant combinations.

Ametryne with surfactants effectively controlled annual grass weeds, but was phytotoxic to sugarcane and reduced plant stand, height, and weight at 0.56 kg/ha with Surfactant-WK at 0.5 or 1.0%. Atrazine at 1.12 kg/ha applied with 1% Surfactant-WK was phytotoxic, but lower rates of atrazine with Surfactant-WK and higher rates with Span-20 and Tween-20 suppressed the crop growth temporarily and crop plants recovered. Activity of both atrazine and ametryne was increased by an increase in temperature and relative humidity. Increased relative humidity had greater effect on herbicidal activity at low temperature while it did not seem to affect the activity of atrazine or ametryne at higher temperatures.

Application of Surfactant-WK alone severely injured sugarcane and grass weeds and phytotoxicity increased with an increase in concentration from 0.50 to 1.0 to 2.0%

(v/v). This indicated that Surfactant-WK had a direct effect on plants.

The following conclusions can be drawn from the research with the herbicides and surfactants tested:

1. Surfactants tend to reduce surface tension and contact angle of herbicide solutions at appropriate concentrations.
2. Water hardness alone up to 1,000 ppm as Ca ions does not affect surface tension and contact angle.
3. Reduction in surface tension and contact angle of herbicide solutions from the addition of surfactant is influenced by the commercial formulation of the herbicide and the surfactant.
4. Ametryne has greater foliar toxicity to sugarcane and two annual grasses, Alexandergrass and broadleaf panicum, than does atrazine.
5. Variety CP63-588 seems to be more sensitive to s-triazine-surfactant treatments than CL41-223.
6. Herbicidal activity of atrazine and ametryne is increased by the addition of surfactants; however, the degree of increase depends upon the type of surfactant.
7. Herbicidal activity of atrazine and ametryne is affected by temperature and relative humidity.
8. Some surfactants e.g. Surfactant-WK, alone have phytotoxic properties.

APPENDIX I
AVERAGE MONTHLY TEMPERATURES, RELATIVE HUMIDITY
AND RAINFALL AT AREC BELLE GLADE
JANUARY, 1975 THROUGH JUNE, 1976

Month	Temperature (°C)			Relative Humidity (%)			Rainfall
	Max.	Min.	Average	Max.	Min.	Average	(mm)
1975							
Jan.	26.8	14.5	20.7	100	48	74	2.1
Feb.	27.7	14.8	21.3	100	44	72	6.4
Mar.	27.8	17.1	22.5	100	39	70	11.5
April	29.8	16.1	23.0	100	38	69	44.2
May	31.6	19.6	25.6	100	46	73	126.0
June	39.9	21.1	26.5	100	51	76	172.4
July	31.7	2.15	26.6	100	56	78	347.5
Aug.	32.5	21.7	27.1	100	50	75	130.3
Sept.	31.9	21.6	26.8	100	58	79	202.5
Oct.	30.1	19.5	24.8	100	54	77	145.8
Nov.	26.1	14.6	20.4	100	47	74	13.5
Dec.	24.4	11.1	17.8	100	41	71	4.8
1976							
Jan.	22.8	9.7	16.3	100	40	70	10.2
Feb.	24.4	11.9	18.2	100	42	71	73.8
Mar.	27.7	15.5	21.6	100	40	70	35.9
April	28.2	15.4	21.8	100	33	67	23.4
May	29.8	19.4	24.6	100	57	79	199.1
June	30.3	20.6	25.5	100	58	79	98.4

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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